Digitized by the Internet Archive
in 2013

http://archive.org/details/researchnotes31rock

arch 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-311

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

CLEMSON UNIVERSITY LIBRARY
JUN 10 1976
SCI. TECH. & AGR. DIV.

INSECTS: A Guide to Their Collection, Identification, Preservation, and Shipment

John D. Stein[1]

Homeowners can send insects to their State extension entomologist for identification. The basic requirements for proper collection, preservation, and shipment of insects are summarized briefly here. A reference table lists 184 typical or prevalent insects associated with 52 tree and shrub hosts found in North and South Dakota.

Keywords: Insect collection, insect identification.

Introduction

Current urban forestry programs emphasize protection and management of planted trees. A survival survey in the Plains area indicated that 39 percent of all trees encountered were dead (Dahl 1940), with the majority mortality factor attributed to insects. Thus it is desirable to identify the insects responsible for damage, determine their biology, establish whether the insect is a new pest or a new outbreak of an old pest, and recommend control measures, if appropriate. A common question from property owners is, "How do we get this information?"

This Note was compiled to inform the public about who to contact for insect identification, and how to adequately collect, preserve, and ship specimens to the insect specialist.

Collection and Identification

Ideally, insect collections shipped for species determination should include 5 to 20 specimens, and represent all the different stages of the insect pest. Samples should be carefully preserved, and information concerning the date, location, host material, feeding habits, and extent of the infestation should be attached to each sample. Your State extension entomologist will identify insects, and provide current recommendations for control. Your local county agent can provide the name and address of the extension entomologist for your State.

Tree and shrub hosts of the 184 insects listed in table 1 are based upon research findings at the Shelterbelt Laboratory in Bottineau, North Dakota. The table lists the more typical representatives of certain insect groups or the more prevalent insects that attack a particular tree species.

Additional information on identification, biology, host, and distribution of those insects listed in the table is available in other publications (Baker 1972, Stein and Kennedy 1972).

Preservation and Shipment

Flies, wasps, plant bugs, and **beetles** can be killed in either 70 percent alcohol or a chloroform bottle. Those killed in alcohol are preserved, and can be shipped in the same material; those killed with chloroform should be transferred to alcohol or placed between layers of cleansing tissues in a pill box or a cigar-type box for shipment. **Adult moths** and **butterflies** may be killed by either method, but should be shipped between layers of cleansing tissues, not in alcohol. **Soft-bodied specimens** and **immature stages of any insect** should be killed by dropping them in boiling water for 1 or 2 minutes,

[1]*Associate Entomologist, located at the Station's Shelterbelt Laboratory at Bottineau, in cooperation with North Dakota State University—Bottineau Branch; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

and then transferred to vials that contain 70 percent alcohol for shipment. The boiling water prevents immatures from turning black.

Vials containing liquids must be wrapped separately in mailing tubes with adequate packing so they cannot move around. Dried insect material to be shipped in pill boxes or cigar-type boxes should be packed inside a second container with at least 2 inches of excelsior on all sides to hold the box in place. Invariably, **insects sent in ordinary envelopes are crushed and worthless.**

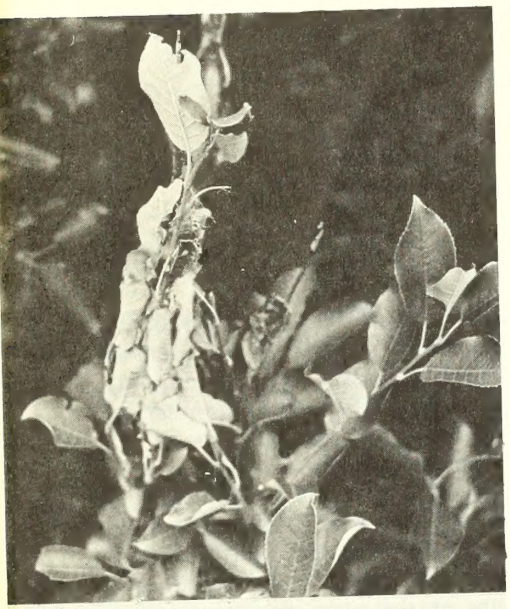
Before shipment you should again check to make sure that labels with the complete collection information are attached to the proper specimens.

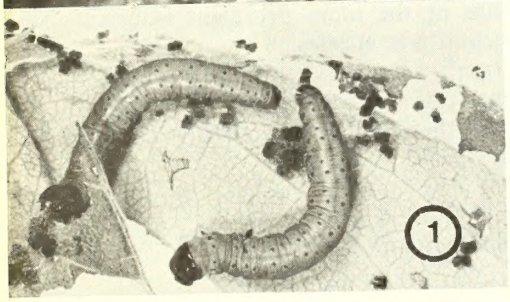
Literature Cited

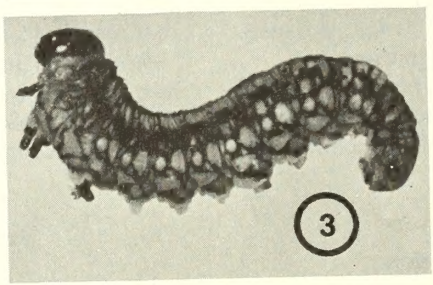
Baker, Whiteford L.
1972. Eastern forest insects. U.S. Dep. Agric., Misc. Publ. 1175, 642 p. Gov. Print. Off., Wash., D.C.

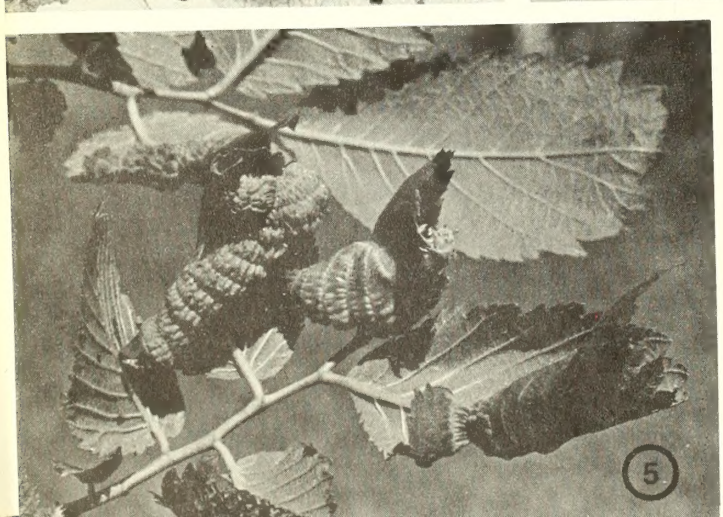
Dahl, Jerome.
1940. Progress and development of the Prairie States Forestry Project. J. For. 38:301-306.

Stein, John D., and Patrick C. Kennedy.
1972. Key to shelterbelt insects in the northern Great Plains. USDA For. Serv. Res. Pap. RM-85, 153 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.









1 *Archips cerasivoranus*
(uglynest caterpillar)
Top: webbed foliage
Bottom: larvae

2 *Clastoptera proteus*
(dogwood spittlebug)

3 *Diprion similis*
(introduced pine sawfly)

4 *Disonycha alternata*
(a chrysomelid leaf beetle)

5 *Eriosoma americanum*
(woolly elm aphid)

6 *Mordwilkoja vagabunda*
(poplar vagabond aphid)

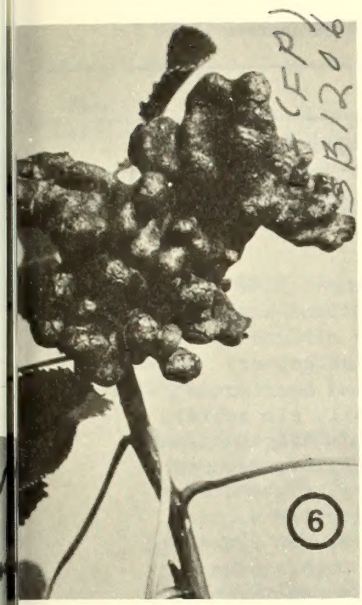
7 *Neoborus amoenus*
(ash plant bug)

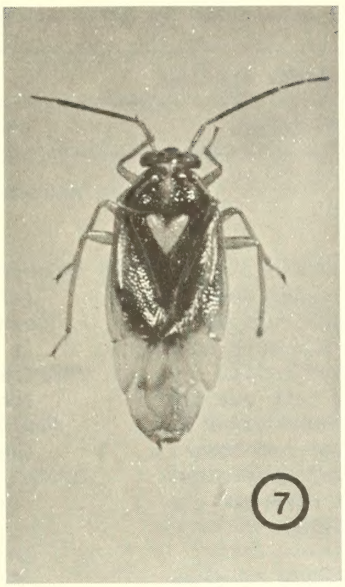
8 *Pachypsylla celtidismamma*
(hackberry nipplegall maker)

9 *Pemphigus populicaulis*
(poplar leaf-petiolegall aphid)

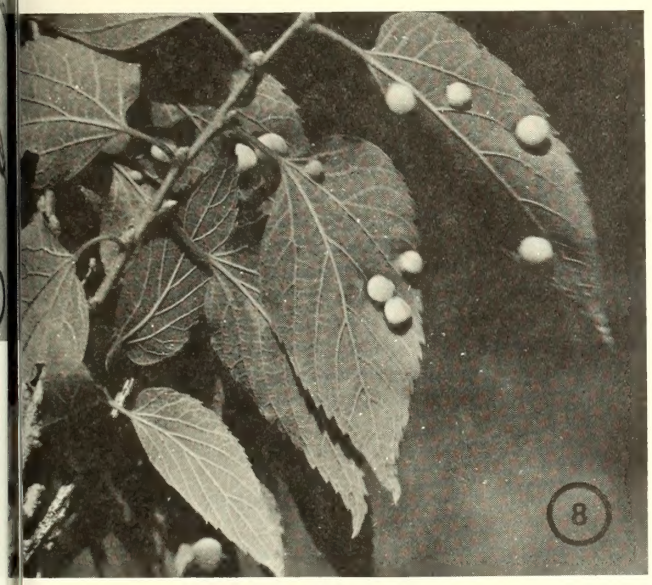
10 *Pulvinaria innumerabilis*
(cottony maple scale)

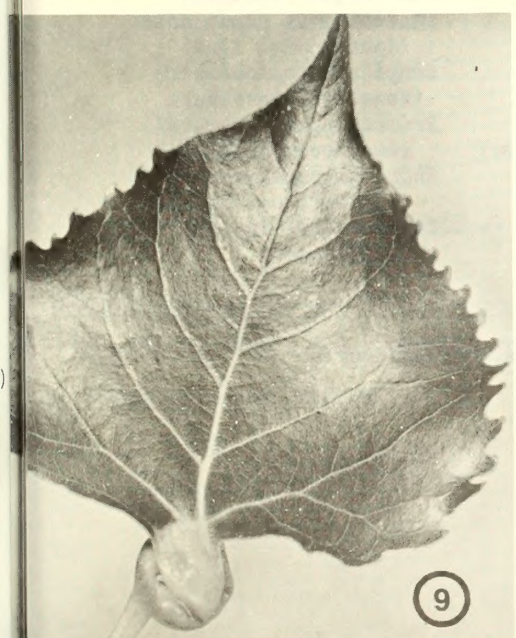
11 *Vasates quadripedes*
(maple bladdergall mite)


6


7

10


8


9

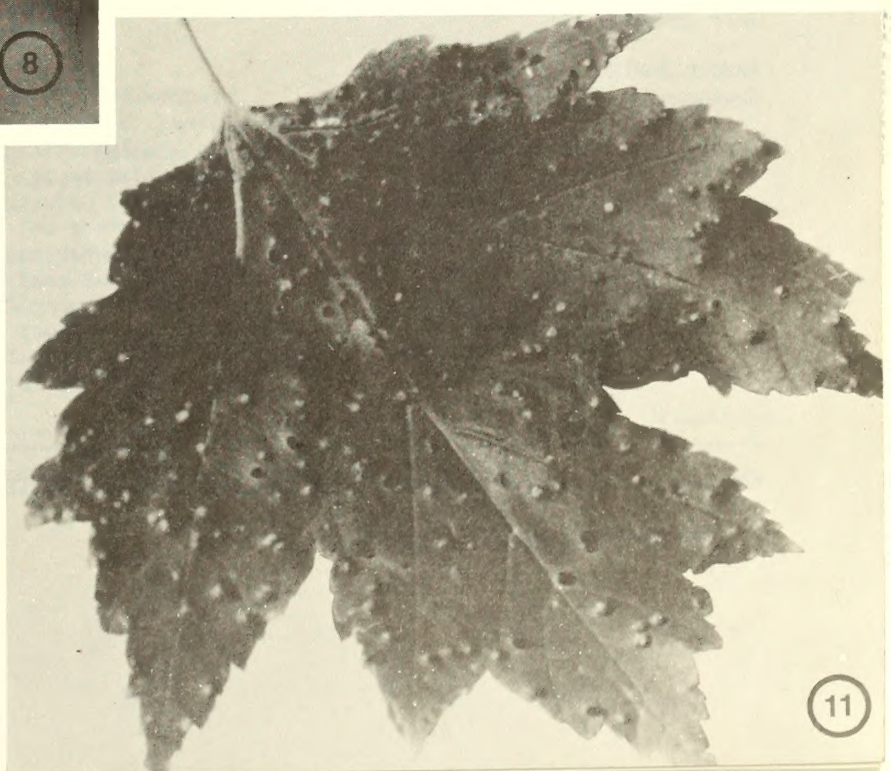

11

Table 1.--Common insects found on trees and shrubs in North and South Dakota

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
AMERICAN ELM *Ulmus americana*	*Alsophila pometaria* (fall cankerworm) *Cimbex americana* (elm sawfly) *Ennomos subsignarius* (elm spanworm) *Erannis tiliaria* (linden looper) *Hyphantria cunea* (fall webworm) *Nymphalis antiopa* (mourningcloak butterfly) *Pyrrhalta luteola* (elm leaf beetle)	*Dicerca divaricata* (a flatheaded wood borer) *Hylurgopinus rufipes* (native elm bark beetle) *Magdalis armicollis* (red elm bark weevil) *Neoclytus acuminatus* (redheaded ash borer) *Scolytus multistriatus* (smaller European elm bark beetle)	*Corythucha ulmi* (elm lace bug) *Cuerna striata* (a leafhopper) ****Eriosoma americanum*[2] (woolly elm aphid) *Stictocephala bubalus* (buffalo treehopper)
AMERICAN PLUM *Prunus americana*	*Alsophila pometaria* (fall cankerworm) *Caliroa cerasi* (pearslug) *Hyphantria cunea* (fall webworm) *Neurotoma inconspicua* (plum webspinning sawfly) *Paleacrita vernata* (spring cankerworm)	*Coccotorus hirsutus* (sandcherry weevil) *Coccotorus scutellaris* (plum gouger) *Conopia pictipes* (lesser peachtree borer) *Conotrachelus nenuphar* (plum curculio) *Hyperplatys aspersus* (a roundheaded wood borer)	*Aphis setariae* (rusty plum aphid) *Asiphonaphis pruni* (a plum aphid) *Empoasca fabae* (potato leafhopper) ****Eriophyes emarginate* (a finger gall mite) *Macropsis trimaculata* (plum leafhopper) *Stictocephala taurina* (a treehopper)
AMUR MAPLE -- (see silver maple) *Acer ginnala*			
ARNOLD HAWTHORN *Crataegus arnoldiana*	*Acrobasis indiginella* (a leaf crumpler) *Antheraea polyphemus* (polyphemus moth) *Caliroa cerasi* (pearslug) *Hyalophora cecropia* (cecropia moth)	*Saperda candida* (roundheaded apple tree borer) *Xylotrechus convergens* (a roundheaded wood borer)	*Chaitophorus populicola* (aphid) *Corythucha cydoniae* (hawthorn lace bug) *Eriosoma lanigerum* (woolly apple aphid) *Rhopalosiphum fitchii* (aphid) *Telamona tristis* (treehopper)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[2]Illustrated on page 2.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
AUSTRIAN PINE -- (see ponderosa pine) *Pinus nigra*			
BLACK HILLS SPRUCE -- (see blue spruce) *Picea glauca* var. *densata*			
BLUE SPRUCE *Picea pungens*	*Archippus packardianus* (a caterpillar) *Choristoneura fumiferana* (spruce budworm) *Epizeuxis aemula* (a spruce cutworm) *Pikonema alaskensis* (yellowheaded spruce sawfly) *Taniva albolineana* (spruce needleminer)	*Dioryctria reniculella* (spruce coneworm) *Dioryctria zimmerman* (Zimmerman pine moth) *Pissodes strobi* (white pine weevil) *Scolytus piceae* (a spruce bark beetle)	*Nalepella halourga* (a mite) *Phenacaspis pinifoliae* (pine needle scale) *Tetranychus urticae* (twospotted spider mite) *Toumeyella* sp. (a tortoise scale)
BOXELDER *Acer negundo*	*Acronicta americana* (American dagger moth) *Alsophila pometaria* (fall cankerworm) *Halisidota tessellaris* (pale tussock moth) *Paleacrita vernata* (spring cankerworm)	*Dicerca divaricata* (a flatheaded wood borer) *Prionoxystus robiniae* (carpenterworm) ****Proteoteras willingana*** (boxelder twig borer) *Tremex columba* (pigeon tremex)	****Aceria negundi*** (warty leafgall) *Lecanium corni* (European fruit lecanium) *Periphyllus negundinis* (boxelder aphid) *Psylla negundinis* (boxelder psyllid) *Pulvinaria innumerabilis*[3] (cottony maple scale)
BUR OAK *Quercus macrocarpa*	*Acronicta americana* (American dagger moth) *Alsophila pometaria* (fall cankerworm) *Halisidota tessellaris* (pale tussock moth) *Heterocama manteo* (variable oakleaf caterpillar) *Malacosoma disstria* (forest tent caterpillar)	*Agrilus bilineatus* (twolined chestnut borer) *Conotrachelus posticatus* (an acorn weevil) *Curculio iowensis* (an acorn weevil) *Curculio strictus* (an acorn weevil) *Elaphidion mucronatum* (spined bark borer) *Elaphidionoides villosus* (twig pruner)	****Aceria querci*** (a blister gall mite) ****Andricus ignotus*** (woolly oak gall) *Corythucha arcuata* (oak lace bug) ****Disholcaspis quercusmamma*** (oak bullet gall) *Heliria molaris* (a treehopper) *Telamona maculata* (a treehopper)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[3]Illustrated on page 3.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
	Paleacrita vernata (spring cankerworm)	*Prionus imbricornis* (tilehorned prionus)	*Telamona monticola* (a treehopper) *Telamona spreta* (a treehopper)
CAROLINA (NORWAY) POPLAR -- (see Siouxland cottonwood) *Populus canadensis eugenei*			
CHINKOTA ELM -- (see Siberian elm) *Ulmus pumila* 'Chinkota'			
COMMON CHOKECHERRY *Prunus virginiana*			
	Alsophila pometaria (fall cankerworm) *Archips cerasivoranus*[4] (uglynest caterpillar) *Hyphantria cunea* (fall webworm) *Malacosoma californicum lutescens* (prairie tent caterpillar)	*Chaetophlocus heterodoxus* (a bark beetle) *Clytophorus verrucosus* (a roundheaded wood borer) *Ropalopus sanguinicollis* (a roundheaded wood borer)	*Asiphonaphis pruni* (a plum aphid) ***Contarinia virginianiae* (chokecherry midge) *Gyponana flavilineata* (a leafhopper) *Rhopalosiphum cerasifoliae* (chokecherry aphid) *Tortistilus inermis* (a treehopper)
DROPMORE ELM -- (see Siberian elm) *Ulmus pumila* 'Dropmore'			
EASTERN REDCEDAR *Juniperus virginiana*			
			Lecanium corni (European fruit lecanium) *Lecanium fletcheri* (Fletcher scale)
GOLDEN CURRANT *Ribes aureum*			
		Conopia tipuliformis (caterpillar)	
GOLDEN WILLOW -- (see white willow) *Salix vitellina*			
GREEN ASH *Fraxinus pennsylvanica*			
	Alsophila pometaria (fall cankerworm) *Malacosoma disstria* (forest tent caterpillar)	*Leperisinus aculeatus* (eastern ash bark beetle) *Leperisinus californicus* (a bark beetle)	*Aspidiotus ancylus* (Putnam scale) ***Eriophyes fraxiniflora* (ash flower gall mite)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[4]Illustrated on page 2.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
	Paleacrita vernata (spring cankerworm) *Sphinx chersis* (great ash sphinx) *Tethida cordigera* (blackheaded ash sawfly)	*Neoclytus acuminatus* (redheaded ash borer) *Podosesia syringae fraxini* (ash borer) *Prionoxystus robiniae* (carpenterworm) *Thysanocnemis nr. fraxini* (an ash seed weevil)	*Lecanium corni* (European fruit lecanium) *Neoborus amoenus*[5] (ash plant bug) *Prociphilus fraxinifolii* (leafcurl ash aphid) *Pulvinaria innumerabilis*[5] (cottony maple scale)
HACKBERRY *Celtis occidentalis*			
	Asterocampa clyton (hackberry butterfly) *Calligrapha* sp. (a leaf beetle) *Paleacrita vernata* (spring cankerworm) *Sphinx drupiferarm* (hackberry sphinx)	*Agrilus celti* (a flatheaded wood borer) *Elaphidion mucronatum* (spined bark borer) *Elaphidionoides villosus* (twig pruner) *Phloeotribus dentifrons* (a bark beetle) *Scolytus muticus* (hackberry engraver)	*Aspidiotus ancylus* (Putnam scale) *Pachypsylla celtidismamma*[5] (hackberry nipplegall maker) *Pachypsylla celtidisvesicula* (hackberry blister gall) *Pachypsylla venusta* (hackberry petiolegall)
HANSEN HEDGEROSE *Rosa* sp.			
	Malacosoma californicum lutescens (prairie tent caterpillar)	****Diplolepis spinosa* (rose twiggall) ****Rhabdophaga rosacea* (rosette midge) *Rhynchites bicolor* (rose curculio)	
HARBIN PEAR *Pyrus ussuriensis*			
	Caliroa cerasi (pearslug) *Paleacrita vernata* (spring cankerworm)		****Eriosoma lanigerum* (woolly apple aphid)
HONEYLOCUST *Gleditsia triacanthos*			
	Alsophila pometaria (fall cankerworm) *Datana ministra* (yellownecked caterpillar)	*Xyleborus saxeseni* (a barkbeetle)	*Lecanium corni* (European fruit lecanium) *Macropsis* sp. (a leafhopper) *Pulvinaria innumerabilis*[5] (cottony maple scale)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[5]Illustrated on page 3.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
LATE LILAC *Syringa villosa*			
	Ceratomia undulosa (sphinx moth) *Sphinx chersis* (great ash sphinx) *Sphinx kalmiae* (sphinx moth)	*Podosesia syringae fraxini* (ash borer)	*Stictectphala bubalus* (buffalo treehopper)
LAUREL WILLOW -- (see white willow) *Salix pentandra*			
LILAC -- (see late lilac) *Syringa vulgaris*			
MANCHURIAN CRABAPPLE -- (see Siberian crabapple) *Malus baccata mandshurica*			
MISSOURI RIVER WILLOW -- (see white willow) *Salix missouriensis*			
NORTHWEST POPLAR -- (see Siouxland cottonwood) *Populus deltoides* x *Populus balsamifera*			
PEKING COTONEASTER *Cotoneaster acutifolia*			
	Acrobasis indigenella (leaf crumpler) *Alsophila pometaria* (fall cankerworm) *Malacosoma californicum lutescens* (prairie tent caterpillar) *Paleacrita vernata* (spring cankerworm)		*Ligyrocoris diffusus* (a lygaeid bug)
PLAINS COTTONWOOD -- (see Siouxland cottonwood) *Populus sargentii*			
PONDEROSA PINE *Pinus ponderosa*			
	Cotalpa lanigera (goldsmith beetle) *Diprion similis*[6] (introduced pine sawfly) *Neodiprion fulviceps* (a sawfly) *Neodiprion ventralis* (a sawfly)	*Dioryctria auranticella* (a pine cone moth) *Dioryctria cambiicola* (a pine moth) *Dioryctria gulosella* (a pine moth) *Dioryctria tumicolella* (a pitch moss borer)	*Cinara* sp. (a pine aphid) *Cuerna striata* (a leafhopper) *Phenacaspis pinifoliae* (pine needle scale)

[6] Illustrated on page 2.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
		Dioryctria zimmermani (Zimmerman pine moth) *Neoclytus acuminatus* (redheaded ash borer) *Orthotomicus caelatus* (a bark beetle) *Petrova luculentana* (pine pitch-nodule maker) *Pogonocherus mixtus* (a roundheaded wood borer) *Rhyacionia bushnelli* (western pine tip moth)	
REDOSIER DOGWOOD *Cornus stolonifera*			
	Acleris sp. (a budworm) *Macremphytus testaceus* (a sawfly)	*Oberea tripunctata* (dogwood twig borer)	*Aspidiotus ancylus* (Putnam scale) *Clastoptera proteus*[7] (dogwood spittlebug) *Pulvinaria innumerabilis*[8] (cottony maple scale)
ROBUSTA POPLAR -- (see Siouxland cottonwood) *Populus angulata* x *Populus nigra*			
ROCKY MOUNTAIN JUNIPER -- (see eastern redcedar) *Juniperus scopulorum*			
RUSSIAN ALMOND -- (see American plum) *Prunus tenella*			
RUSSIAN OLIVE *Elaeagnus angustifolia*			
	Choristoneura rosaceanus (obliquebanded leafroller) *Estigmene acrea* (saltmarsh caterpillar)		*Capitophorus* sp. (an aphid) *Empoasca fabae* (potato leafhopper)
SASKATOON SERVICEBERRY *Amelanchier alnifolia*			
	Alsophila pometaria (fall cankerworm) *Archips cerasivoranus*[7] (uglynest caterpillar)	*Chaetophloeus heterodoxus* (a barkbeetle)	*Stictocephala* sp. (a treehopper)
SCOTCH PINE -- (see ponderosa pine) *Pinus sylvestris*			
SIBERIAN APRICOT -- (see American plum) *Prunus armeniaca sibirica*			

[7]Illustrated on page 2.
[8]Illustrated on page 3.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
SIBERIAN CRABAPPLE *Malus baccata*			
	Alsophila pometaria (fall cankerworm) *Biston cognataria* (pepper-and-salt moth) *Erannis tiliaria* (linden looper) *Paleacrita vernata* (spring cankerworm)	*Conotrachelus nenuphar* (plum curculio) *Hyperplatys aspersus* (a roundheaded wood borer) *Saperda candida* (roundheaded apple tree borer)	*Eriosoma lanigerum* (woolly apple aphid)
SIBERIAN ELM *Ulmus pumila*			
	Alsophila pometaria (fall cankerworm) *Antheraea polyphemus* (polyphemus moth) *Calligrapha scalaris* (elm calligrapha) *Cimbex americana* (elm sawfly) *Heterocampa guttivitta* (saddled prominent)	*Astyleiopus variegatus* (a roundheaded wood borer) *Magdalis armicollis* (red elm bark weevil) *Mecas mornata* (a roundheaded wood borer) *Saperda tridentata* (elm borer)	**_Aceria_ sp. (a finger gall mite) *Deraeocoris histrio* (a plant bug) *Empoasca bipunctata* (a leafhopper) *Lecanium corni* (European fruit lecanium) *Stictocephala taurina* (a treehopper) *Tortistilus inermis* (a treehopper)
SIBERIAN LARCH *Larix sibirica*			
	Anavitrinella pampinaria (cranberry spanworm) *Coleophora laricella* (larch casebearer) *Pristiphora erichsonii* (larch sawfly) *Semiothisa sexmaculata* (an inchworm)	*Dioryctria abietvorella* (a coneworm)	
SIBERIAN PEASHRUB *Caragana arborescens*			
	Epicauta fabricii (ashgray blister beetle) *Epicauta subglabra* (caragana blister beetle) *Lytta nuttallii* (Nuttall blister beetle)	*Bruchophagus caraganae* (caragana seed chalcid)	*Acyrthosiphon caraganae* (caragana aphid) *Empoasca fabae* (potato leafhopper) *Macrosiphum caraganae* (an aphid) *Stictocephala bubalus* (buffalo treehopper) *Stictocephala taurina* (a treehopper)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
SILVERBERRY -- (see Russian olive) *Elaeagnus commutata*			
SILVER BUFFALOBERRY *Shepherdia argentea*			
	Datana sp. (a caterpillar) *Erannis tiliaria* (linden looper)		*Paratrioza arbolensis* (a psyllid) *Psylla magnicauda* (a psyllid)
SILVER MAPLE *Acer saccharinum*			
	Erannis tiliaria (linden looper) *Halisidota maculosus* (spotted tussock moth) *Paleacrita vernata* (spring cankerworm)	*Chrysobothris femorata* (flatheaded appletree borer)	*Aspidiotus ancylus* (Putnam scale) *Pulvinaria innumerabilis* (cottony maple scale) ****Vasates quadripedes*[9] (maple bladdergall mite)
SIOUXLAND COTTONWOOD *Populus deltoides* 'Siouxland'			
	Acronicta lepusculina (cottonwood dagger moth) *Alsophila pometaria* (fall cankerworm) *Chrysomela scripta* (cottonwood leaf beetle) *Hyphantria cunea* (fall webworm) ****Phyllocolpa bozemani* (poplar leaffolding sawfly)	*Agrilus liragus* (bronze poplar borer) *Cryptorhynchus lapathi* (poplar-and-willow borer) *Dicerca divaricata* (a flatheaded wood borer) *Prionoxystus robiniae* (carpenterworm) *Saperda calcarata* (poplar borer)	****Aceria parapopuli* (poplar bud gall mite) ****Mordwilkoja vagabunda*[9] (poplar vagabond aphid) *Neothomasia populicola* (cloudywinged cottonwood leaf aphid) ****Pemphigus populicaulis*[9] (poplar leaf-petiolegall aphid *Pterocomma populifoliae* (reddishbrown poplar aphid)
TATARIAN HONEYSUCKLE *Lonicera tatarica*			
	Linsleya sphaericollis (a blister beetle) *Zaraea inflata* (honeysuckle sawfly)		*Empoasca fabae* (potato leafhopper) *Macrosteles fascifrons* (aster leafhopper) *Psylla negundinis* (boxelder psyllid)
WESTERN SANDCHERRY -- (see American plum) *Prunus pumila besseyi*			
WHITE SPRUCE -- (see blue spruce) *Picea glauca*			

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[9] Illustrated on page 3.

Table 1.--Continued

Tree species	Insect species		
	Leaf feeders	Borers	Sucking insects
WHITE WILLOW *Salix alba*	*Antheraea polyphemus* (polyphemus moth) *Chrysomela scripta* (cottonwood leaf beetle) *Cimbex americana* (elm sawfly) *Disonycha alternata*[10] (a chrysomelid leaf beetle) *Hyphantria cunea* (fall webworm)	*Cryptorhynchus lapathi* (poplar-and-willow borer) *Janus abbreviatus* (willow shoot sawfly) ******Pontania proxima* (bean gall sawfly) *Prionoxystus robiniae* (carpenterworm)	*Cavariella* sp. (a willow aphid) *Pterocomma* sp. (a willow aphid) *Stictocephala bubalus* (buffalo treehopper)

**Damage by this species results in abnormal growths, swellings, or leaf curls.

[10]Illustrated on page 2.

March 1976

USDA FOREST SERVICE
RESEARCH NOTE RM- 312

CLEMSON UNIVERSITY LIBRARY
JUN 10 1976
OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Direct Seeding Ponderosa Pine on Recent Burns in Arizona

W. J. Rietveld and L. J. Heidmann[1]

The significant factors determining success of direct seeding are those affecting seedling survival, particularly moisture stress and frost heaving. Because there is little or no control of these factors, the results of direct seeding are extremely variable, even on the most favorable sites. Direct seeding recent burns, even by spot seeding, is of limited usefulness in the Southwest because of high cost and variability of results. The method should be reserved as a flexible tool to promptly regenerate only the best sites when planting stock is unavailable.

Keywords: Forest regeneration, direct seeding, frost heaving, ponderosa pine.

Research has demonstrated that planting forest trees is the most positive way to start new stands when and where needed, but planting is expensive. Direct seeding has the potential of being more economical and flexible than planting, but is less reliable.

The best time to plant or seed is immediately after disturbance. Regeneration problems become more difficult as reforestation is delayed. Recently burned areas present the fewest obstacles to direct seeding, and constitute an excellent test situation to determine the success potential of direct seeding in the Southwest.

Habitat conditions for seedeating rodents and birds are least desirable immediately following a fire. A hot burn also destroys most of the herbaceous seeds, so new pine seedlings compete with fewer grass and weed seedlings of their own age. This study examined the problems and prospects of direct seeding on recent burns.

[1]*Plant Physiologist and Silviculturist, respectively, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Literature Review

Lavin (1955) found that fresh burns in northern Arizona, on which the vegetation was largely destroyed and the soil surface covered with a layer of loose ash, were good sites for seeding grasses. The practice of seeding grasses after fires has been curtailed in recent years, however, because the grasses compete strongly with tree seedlings in later ponderosa pine regeneration programs. Larson and Schubert (1969b) found that competition for soil moisture was the main factor in competition between grasses and ponderosa pine seedlings. Pine seedlings survived and grew best on plots completely cleared of other vegetation. Grasses start root growth earlier, grow faster, deplete soil moisture rapidly to lower levels, and are capable of enduring more drought than the pines. Although partial shade from grass and weeds favors germination of pine seeds, the later effects of competition are detrimental (Pearson 1950).

Water stress during germination and initial development of ponderosa pine seedlings is one of the main reasons for poor success with direct seeding (Larson and Schubert 1969a). A slightly negative (-3 bars) water potential stimulated germination, but potentials below -7 bars greatly depressed germination. Seeds alternately wetted and dried several times germinated as well as unwetted seeds, and significantly better than seeds soaked

for 24 hours without aeration. Root penetration, root dry weight, and cotyledon length decreased with decreased water potential of the soil solutions. Another significant finding was that seedlings that germinated under stress conditions grew poorly even if they subsequently were well watered.

Low soil water potential is usually the result of the precipitation pattern, competition of herbaceous vegetation, or a combination of the two (Pearson 1942, 1950; Heidmann 1969; Larson and Schubert 1969b; Schubert et al. 1970). Even in the absence of competing vegetation, there is no control over the precipitation pattern, and direct-seeded pine seedlings are more susceptible than planted seedlings to temporary drought.

Study Areas and Methods

The study was established on two spring burns that occurred in successive years on the Coconino National Forest, Arizona. The Kelly Burn consumed 3,550 acres in April 1971, and the Rattle Burn consumed 714 acres in May 1972. Although only two burns were available, contrasting soil and site conditions are representative of those found on the Coconino Plateau in northern Arizona. On the Kelly Burn experimental plot, site index was 65 (Minor 1964) at 7,470 feet elevation; soils were Kelly sandy loam derived from basalt and cinders. On the Rattle Burn plot, site index was 98, and elevation was 6,760 feet; soil was Soldier sandy loam derived from limestone and sandstone parent materials.

Kelly Burn Experiment

Direct seeding methods tested on the Kelly Burn were broadcast, broadcast and rake, and seed spot. Viable seeds of local origin were sown at rates of 2, 4, and 8 pounds per acre by each seeding method. There were four replications of the nine treatments; one replication consisted of four circular 1-milacre subplots treated alike. The broadcast treatment involved spreading seeds evenly over the soil surface with no attempt to cover them. In the broadcast-and-rake treatment, seeds were worked into the soil with a garden rake. Seed spots were shallow depressions made with a hoe in which the seeds were covered uniformly with 0.5 inch of soil and compressed. Four seeds were placed in each spot; the number of seed spots per milacre increased with the seeding rate. The Kelly Burn was seeded on July 14, 1971, 2 days before summer showers began. Schubert (1974) recommends that direct seeding in the Southwest be done in late June or early July, just before the beginning of summer rains, to minimize the period seeds are susceptible to rodent and bird depredation.

Rattle Burn Experiment

Because of lessons learned from the Kelly Burn experiment in 1971, only seed-spot and broadcast-and-rake treatments at rates of 4 and 8 pounds of seed per acre were tested on the Rattle Burn in 1972. In addition, three frost-heaving "retardants"—gypsum (calcium sulfate), sodium tetraphosphate, and coarse sand—were tested for their capacity to reduce frost heaving of seedlings, and for their interaction with seeding method. Coarse sand was applied as a 0.5-inch layer over the seed spots only; it was impractical to cover an entire broadcast-and-rake subplot. There were 8 replications of the 14 treatments, each represented by 1 rectangular milacre subplot.

On designated subplots, either gypsum or sodium tetraphosphate were added to the surface 1 inch of soil at rates of 1 percent and 0.5 percent, respectively. Seeds of local origin, but from a different seed lot than that used in the Kelly Burn experiment, were sown by the prescribed methods and rates on July 6, 1972. Summer rainfall began 10 days later.

The measures used to retard frost heaving and application rates employed were those found to be most promising and nontoxic in concurrent studies by Heidmann and Thorud (1976). Gypsum lowers the freezing point of soil water, while sodium tetraphosphate disperses the colloidal fraction of the soil. Coarse sand is thought to disrupt the migration of water to the soil surface to form the ice lenses responsible for heaving.

General

All plots were examined for emerging and dead seedlings at weekly intervals during the germination period, and for dead seedlings at intervals of approximately 1 month during 2 growing seasons. Causes of mortality were noted when possible.

The rate and completeness of germination were incorporated in "speed of emergence," a parameter adapted from Maguire's (1962) "speed of germination." Here speed of emergence (SE) is defined as: SE = Σ number new emerging seedlings/number days from beginning of rainfall. Speed of emergence was calculated for each inventory and summed over the germination period. A higher value reflects earlier emergence of a large number of seedlings. Percent stocking was also calculated; milacre subplots supporting at least one live seedling were considered stocked. On the Rattle Burn experiment, emerging seedlings on three plots were marked with color-coded nails in an attempt to link the date of emergence and fate of individual seedlings.

Results and Discussion

Kelly Burn Experiment

Germination.—Spot seeding resulted in earlier and more complete germination, expressed as speed of emergence and number of seedlings per acre, than either the broadcast-and-rake or broadcast treatments (fig. 1). Emerging seedlings were first noted in seed spots on August 5, 20 days after the beginning of the summer rains. By August 8, germination in seed spots (3,800 seedlings/acre) was considerably more advanced than on broadcast-and-rake subplots (1,350), which in turn was far better than the broadcast treatment (300).

Differences in speed of emergence among the three seeding methods were highly significant. Differences in number of seedlings per acre between the seed-spot and broadcast-and-rake methods were not significant beyond September of the first growing season, however. The broadcast-and-rake and seed-spot methods were similar in terms of percent stocking (fig. 2), but the broadcast method still showed a very low success level.

The differences in speed of emergence and number of seedlings per acre among the three seeding rates were highly significant and linear. The abundance of seedlings germinating early and number of seedlings per acre increased directly with seeding rate. However, the 2-lb/acre rate resulted in an unacceptably small seedling population, even with spot seeding.

The initial success of the seed-spot method, as evidenced by the more rapid and complete germination on the Kelly Burn, can be attributed to the uniform covering and the compaction of soil over the seeds to facilitate transfer of moisture. The slight depression of the seed spot also served to trap rain water. In contrast, seeds broadcast and raked into the soil are covered to variable depths, often too deep or too shallow, and are surrounded by loose soil which limits the transfer of water from soil to seed. Broadcast seeds, which depend on soil washing to cover them sufficiently for germination to occur, may be inadequately covered or washed away. For example, heavy showers in late July 1971, caused some sheet erosion which probably carried away some seed from the broadcast-and-rake and broadcast-seeded subplots.

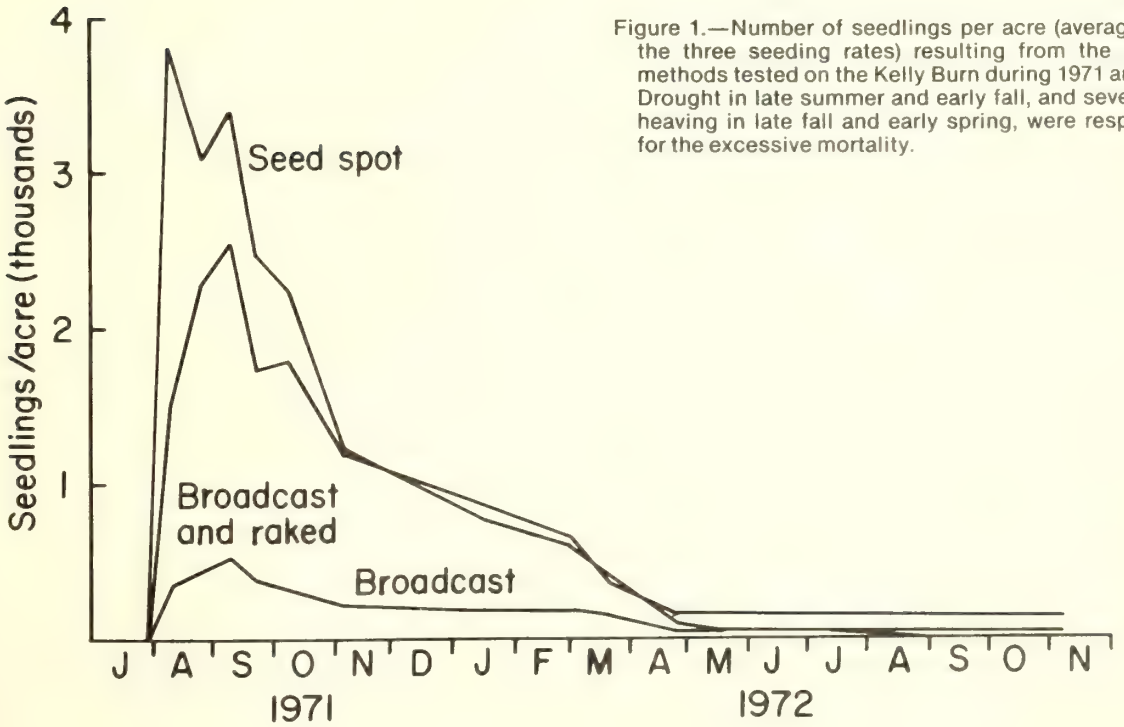


Figure 1.—Number of seedlings per acre (averaged over the three seeding rates) resulting from the seeding methods tested on the Kelly Burn during 1971 and 1972. Drought in late summer and early fall, and severe frost heaving in late fall and early spring, were responsible for the excessive mortality.

Seedling Mortality.—While seed germination was generally good in the seed-spot and broadcast-and-rake treatments, seedling mortality began immediately and involved a number of agents. Drought and frost heaving were the most devastating. By May 1972 there were only a few surviving seedlings on the entire experiment (fig. 1).

Some of the first seedlings to emerge were clipped by rodents or birds, and only their tiny stubs remained to record their emergence. Clipping was not extensive, however, and occurred for only a short period of time.

Erosion and burial caused by heavy showers also accounted for small losses during the germination period when seedlings were small and shallow rooted. Partial burial of seedlings by soil washing did not seem harmful.

Competition from a heavy growth of weeds and grass contributed to some seedling losses to drought during the summer when rainfall was sparse for 1- to 2-week periods, and for heavier losses during September and early October when rainfall declined (fig. 1).

The greatest seedling loss, however, was caused by frost heaving during late fall and early spring (fig. 1). By July 1972, after 2 periods of frost heaving and a severe spring drought, only 10 seedlings were alive on the entire experiment. These were concentrated on a part of the study area where a few dead snags provided partial shade. All seedlings, regardless of age or method of seeding, appeared to be equally susceptible to frost heaving. Pine seedlings whose deaths were ascribed to frost heaving either lay on the ground partly uprooted, remained upright but considerably raised, or were broken off at the root collar. Some seedlings survived, although they were raised a half-inch or more. Some seedlings listed as dead from drought may have died from injuries inflicted by heaving stresses on the root collar and root system.

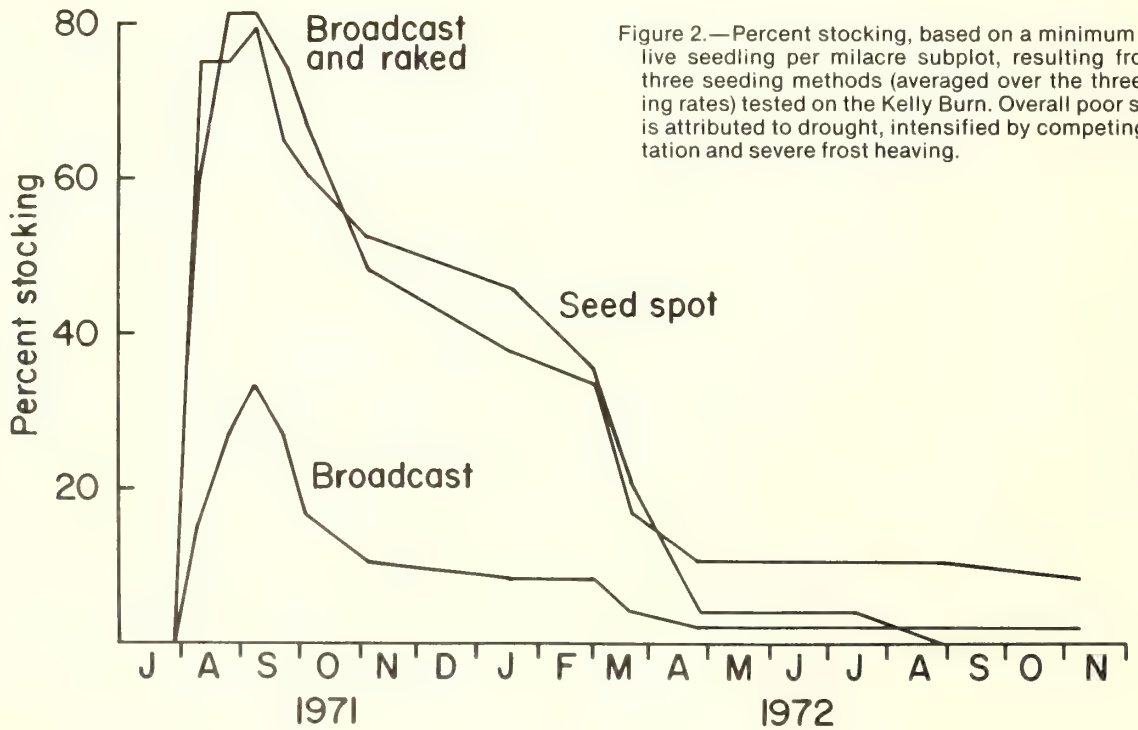


Figure 2.—Percent stocking, based on a minimum of one live seedling per milacre subplot, resulting from the three seeding methods (averaged over the three seeding rates) tested on the Kelly Burn. Overall poor survival is attributed to drought, intensified by competing vegetation and severe frost heaving.

Rattle Burn Experiment

Applying sodium tetraphosphate to the soil prior to seeding significantly depressed speed of emergence and number of seedlings (table 1). Gypsum was also inhibitory in some instances, but the effect was variable and may have been due to chance. Germination and number of seedlings were highest on subplots receiving no chemicals and on seed spots covered with sand. The sand acted as a mulch during the summer, but most of it was washed away during heavy rains in October 1972.

Depressed germination caused by sodium tetraphosphate and possibly gypsum was unexpected since these compounds were found to be nontoxic at the same concentrations in the laboratory (Heidmann and Thorud 1976). The soils were similar in the two cases: a fine sandy loam on the Rattle Burn compared to a fine silica sand used in the laboratory tests. A possible explanation for the observed toxicity may involve fire-induced soil water repellency and its effect on soil cation exchange capacity.

Germination.—The seed-spot method was clearly superior in speed of emergence and number of seedlings (table 1, fig. 3). Following the onset of summer showers on July 16, numerous seedlings were apparent in seed spots by July 25 compared

Table 1.--Speed of emergence (SE)[1] and number of seedlings per acre resulting from the two seeding methods and two seeding rates, tested on the Rattle Burn in 1972 and 1973

Seeding method and frost-heaving retardant	Speed of emergence		Seedlings/acre (Nov. 1, 1973)	
	4 lb/acre	8 lb/acre	4 lb/acre	8 lb/acre
			- - no. - -	
SEED SPOT:				
None (control)	0.360	0.895	4,125	8,125
Gypsum	.343	.371	2,500	3,125
Sodium tetraphosphate	.296	.263	1,625	2,625
Sand	.471	.860	2,750	8,875
BROADCAST AND RAKE:				
None (control)	.064	.108	750	1,500
Gypsum	.035	.158	750	2,625
Sodium tetraphosphate	.017	.036	250	625

[1]SE = Σ number new emerging seedlings/number days from beginning of rainfall.

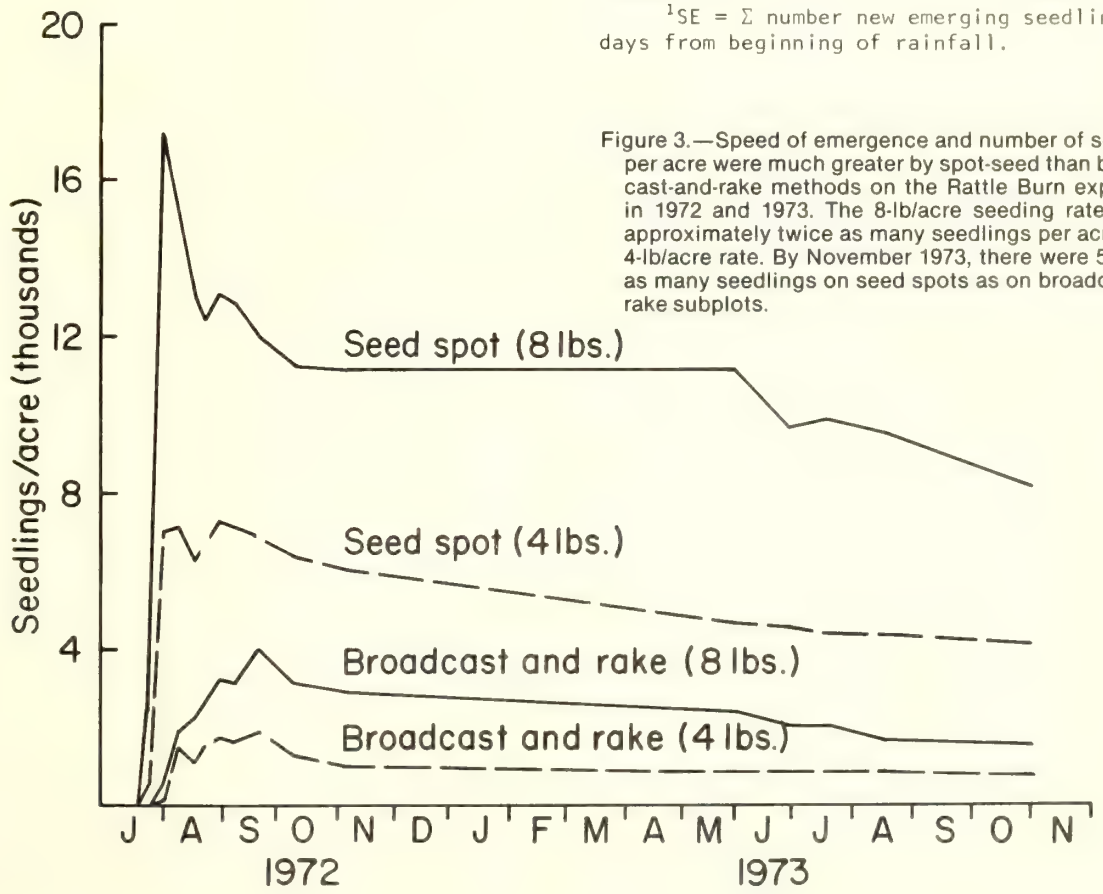


Figure 3.—Speed of emergence and number of seedlings per acre were much greater by spot-seed than by broadcast-and-rake methods on the Rattle Burn experiment in 1972 and 1973. The 8-lb/acre seeding rate yielded approximately twice as many seedlings per acre as the 4-lb/acre rate. By November 1973, there were 5.4 times as many seedlings on seed spots as on broadcast-and-rake subplots.

to only a few seedlings on broadcast-and-rake subplots by July 31. At the end of 2 growing seasons, spot-seeded plots had 5.4 times as many seedlings per acre (with no frost-heaving control) as broadcast-and-rake plots (table 1). The 8-lb/acre seeding rate yielded approximately twice as many seedlings, by either seeding method, as the 4-lb/acre rate. Percent stocking quickly rose to 100 percent on seed spots and stayed at that level through 2 growing seasons for the 8-lb/acre rate; the 4-lb/acre rate dropped to 75 percent stocking (fig. 4). The broadcast-and-rake method yielded a more scattered distribution of seedlings—62.5 and 50 percent stocking, respectively—after 2 growing seasons.

Percent stocking can be misleading when not used in conjunction with number of seedlings per acre. It is a measure of seedling distribution. Many stocked broadcast-and-rake milacres had only a single live seedling, while most spot-seeded milacres supported several seedlings.

Differences in germination between the two seeding methods were primarily due to the presence of hydrophobic (water-repellent) soils resulting from the fire. Most of the water repellency appeared to be located in the surface inch of soil. Thus depressions made for seed spots penetrated the layer, while raking did not. Water penetrated in seed spots, like small holes in a sheet of plastic, whereas excessive runoff was observed from broadcast-and-rake subplots. Immediately following a rain, dry soil was found at a depth of 0.5 inch. Part of the difference in success of the two methods may also be attributed to seed losses from erosion.

Best results from broadcast-and-rake seeding were observed in locations where soil was considerably disturbed. Apparently, mechanical soil disturbance is needed after eliminating competing vegetation and exposing mineral soil by fire.

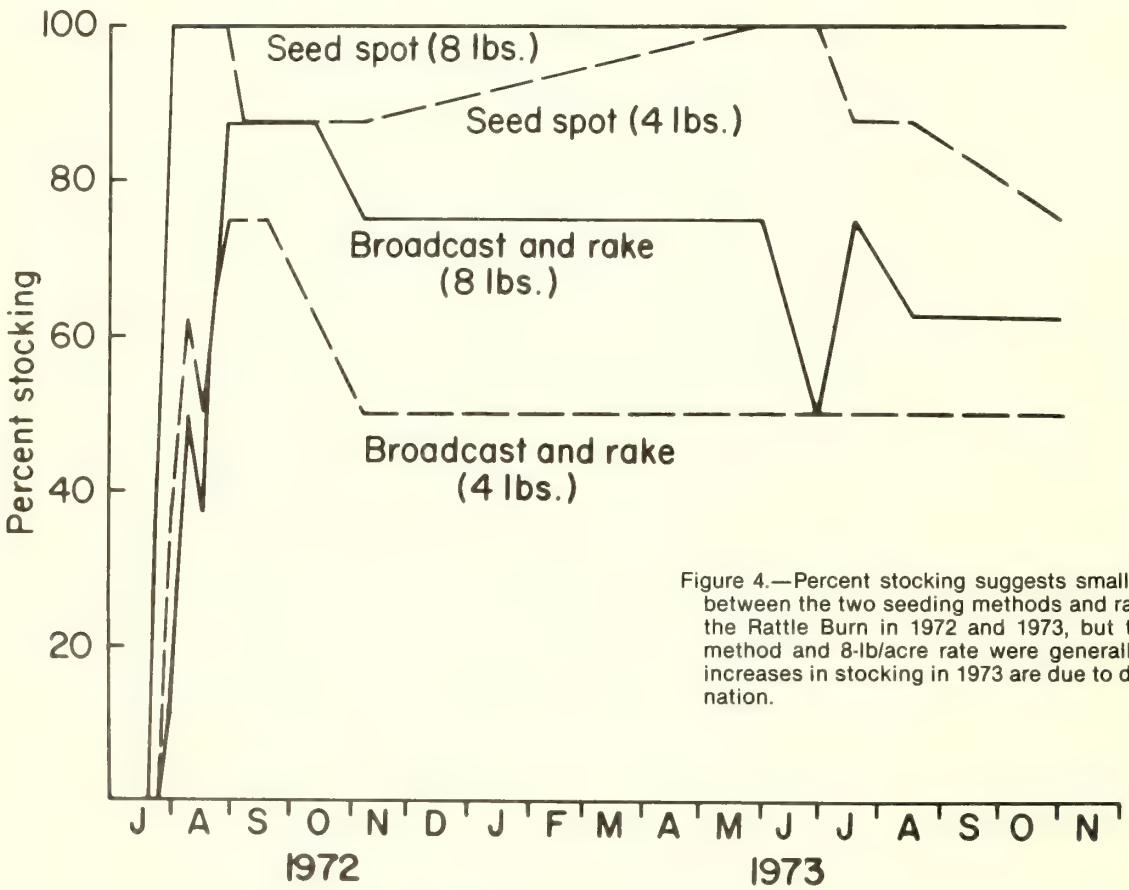


Figure 4.—Percent stocking suggests smaller differences between the two seeding methods and rates tested on the Rattle Burn in 1972 and 1973, but the seed-spot method and 8-lb/acre rate were generally better. The increases in stocking in 1973 are due to delayed germination.

Seedling Mortality.—Differences in number of seedlings and percent stocking at the end of 2 growing seasons were primarily due to differential germination, since mortality was similar in both seed methods (fig. 3). Mortality, not excessive in either method, was due to clipping and drought shortly after germination. More losses due to water stress were also incurred during the fall drought in September and October. A heavy snowpack which developed early and persisted late into the spring of 1973 protected the seedlings from frost heaving, normally prevalent during the first winter. Dead trees on the experimental area, which provided overhead shade to preserve the snowpack, also reduced the severity of day-night thawing and freezing cycles. Losses of 2-year-old seedlings to frost heaving during the winter of 1973-74 were small despite saturated soil conditions conducive to heaving.

Comparisons of seedling survival in relation to germination date was not valid because too few seedlings germinated late in the season, compared to those germinating early. For germination dates within the period July 25 to August 16, represented by adequate numbers of seedlings, survival differences were not significant on June 1, 1973. Larson (1961) found that seedlings germinating early (July) had better survival the following summer than seedlings starting late (August, September).

General

These results demonstrated that the outcome of direct seeding may be extremely variable, depending on the net influence of several factors affecting seed germination and seedling survival. The initial number of seedlings depends mainly upon seeding method and rate, soils, seed predation by rodents and birds, and moisture stress.

While it is not too difficult to obtain satisfactory seed germination, the principal problems limiting success are in keeping those seedlings alive. The seeding method has little effect on such seedling mortality factors as rodent and bird depredation, moisture stress (intensified by competition), browsing, and frost heaving—which can totally eliminate a sizable seedling population. For these reasons, it is extremely difficult to estimate the size of an initial population of seedlings needed to yield a minimum number of surviving seedlings after a specified period of time.

The cost of direct seeding on seed spots, with a minimum rate of 4 pounds of seed per acre, is comparable to planting. Assuming the operational costs of spot seeding at the 4-lb/acre rate and planting 680 seedlings per acre are similar, the current per-acre costs for seed and planting stock are $79 and $33, respectively.[2] Considering the cost comparability, planting is favored because it avoids or seriously reduces the problems with frost heaving, rodent and bird depredation, and variable stocking. Containerized tree seedlings can be raised in as little time as 4 months.

This discussion discourages direct seeding on recent burns, in comparison to planting, at least until solutions are found for the problems of poor seedling survival and variable stocking. Direct seeding, as applied here, is an artificial regeneration method and should be distinguished from natural seeding, which is encouraged by regeneration cuttings and supplemental site preparation. The latter method has good potential for timely, inexpensive regeneration, and is receiving more attention.

Conclusions and Recommendations

The spot-seeding method proved to be consistently better than the broadcast-and-rake method with regard to speed and completeness of germination, and number of seedlings per acre. Distribution of seedlings was similar. The broadcast method was a failure due to slow, incomplete germination and to low numbers of seedlings.

Because of high cost and variability of results, direct seeding has limited potential as a regeneration method on recent burns. Seed should be carefully applied in spots at a rate of at least 4 pounds of seed per acre. Only the best sites should be selected for seeding; clay soils should be avoided. If planting stock from seed of local origin (Schubert and Pitcher 1973) is available, it should be utilized on burns in preference to seeding. When direct seeding fails, time is lost, and it may be necessary to invest more money in site preparation prior to planting.

[2]Personal communication with Dr. John A. Pitcher, U.S. Forest Service, Region 3, Albuquerque, New Mexico. Seed costs are high because Working Capital Fund overhead costs are included. Using commercially collected seed, the cost of 4 pounds of seed (about $32) is still comparable with planting stock on a per-acre basis.

Literature Cited

Heidmann, L. J.
1969. Use of herbicides for planting site preparations in the Southwest. J. For. 67:506-509.

Heidmann, L. J., and David B. Thorud.
1976. Controlling frost heaving of ponderosa pine seedlings in Arizona. USDA For. Serv. Res. Pap. RM- , p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. [In press.]

Larson, M. M.
1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn. Res. Note 66, 4 p. Fort Collins, Colo.

Larson, M. M., and Gilbert H. Schubert.
1969a. Effect of osmotic water stress on germination and initial development of ponderosa pine seedlings. For. Sci. 15:30-36.

Larson, M. M., and Gilbert H. Schubert.
1969b. Root competition between ponderosa pine seedlings and grass. USDA For. Serv. Res. Pap. RM-54, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Lavin, Fred.
1955. Seeding in the Southwestern pine zone for forage improvement and soil protection. U.S. Dep. Agric., Agric. Handb. 89, 52 p.

Maguire, J. D.
1962. Speed of germination—aid in selection and evaluation for seedling emergence and vigor. Crop Sci. 2:176.

Minor, Charles O.
1964. Site-index curves for young-growth ponderosa pine in northern Arizona. U.S. For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pearson, G. A.
1942. Herbaceous vegetation, a factor in natural regeneration of ponderosa pine in the Southwest. Ecol. Monogr. 12:315-338.

Pearson, G. A.
1950. Management of ponderosa pine in the Southwest. U.S. Dep. Agric., Agric. Monogr. 6, 218 p.

Schubert, Gilbert H.
1974. Silviculture of Southwestern ponderosa pine: The status of our knowledge. USDA For. Serv. Res. Pap. RM-123, 71 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Schubert, Gilbert H., L. J. Heidmann, and M. M. Larson.
1970. Artificial reforestation practices for the Southwest. U.S. Dep. Agric., Agric. Handb. 370, 25 p.

Schubert, Gilbert H., and John A. Pitcher.
1973. A provisional tree seed-zone and cone-crop rating system for Arizona and New Mexico. USDA For. Serv. Res. Pap. RM-105, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

PAPER RM-313

March 1976

USDA FOREST SERVICE
RESEARCH NOTE RM-313

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
CLEMSON UNIVERSITY LIBRARY
JUN 10
ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Locating Western Spruce Budworm Egg Masses with Ultraviolet Light

Robert E. Acciavatti[1] and Daniel T. Jennings[2]

Western spruce budworm egg masses on 24-inch (ca. 60 cm) Douglas-fir branches were located more quickly (48 percent faster) and accurately (22 percent more egg masses) with longwave ultraviolet light than with visible light. Most egg masses missed under ultraviolet light (89 percent) were old and parasitized, while almost half of those missed under visible light (42 percent) were new.

Keywords: *Choristoneura occidentalis, Pseudotsuga menziesii,* western spruce budworm detection.

Introduction

Western spruce budworm (*Choristoneura occidentalis* Freeman) infestations in the southern Rocky Mountains are classified, and defoliation predicted for the next year, on the basis of the number of new egg masses found on Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) foliage (McKnight et al. 1970). Branches 24 inches (ca. 60 cm) long are collected from the midcrowns of codominant trees and examined in the laboratory. Needles on each branch are checked carefully in an attempt to find all egg masses. The examination process is time consuming and costly.

Jennings (1968) found that egg masses of the jack-pine budworm (*C. pinus pinus* Freeman) and the eastern spruce budworm (*C. fumiferana* (Clemens)) fluoresced when exposed to longwave ultraviolet light. Newly laid egg masses of the jack-pine budworm fluoresced more distinctly than old or parasitized ones.

During preliminary observations, both green and hatched western spruce budworm egg masses were also found to fluoresce under longwave ultraviolet light. Thus, a study was designed to compare: (1) the efficiency and accuracy of locating newly hatched western spruce budworm egg masses with longwave ultraviolet light and visible light, and (2) the characteristics of egg masses missed under each light source.

Methods and Materials

Field Collection

Midcrown Douglas-fir branches were collected from budworm-infested trees in the Sandia Mountains, near Albuquerque, New Mexico. A total of 80 branches, each with numerous new egg masses, was collected after egg hatch in early August 1975. Branches were cut from trees with a pole pruner. Each branch was pruned to approximately 24 inches (ca. 60 cm), and placed individually in a ¼-bushel (8.8-liter) paper sack. Ten sacks were then bundled together with heavy twine and kept out of direct sunlight while being transported to the laboratory for storage. Each bundle was stored in a walk-in cooler until the branches were examined under the different light sources.

[1]*Entomologist, Forest Insect and Disease Management, State and Private Forestry, Southwestern Region, USDA Forest Service, Albuquerque, N. Mex.*

[2]*Research Entomologist, located at the Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico, Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Laboratory Examination

Infested branches were examined within 2 weeks of collection by four college students. The students, two women and two men, had no previous experience checking foliage for budworm egg masses.

For the ultraviolet light examination, egg masses were counted in a darkened room under two GE 15-watt black-light lamps (F-15T8/BLB)[3] mounted in an 18-inch (ca. 46 cm) standard desk-type receptacle. The lamp was mounted about 1 foot (ca. 30 cm) above a worktable covered with black construction paper to minimize reflected light.

A battery-operated penlight was used to identify suspect objects, such as pitch droplets, spider egg cases, and bird droppings, which fluoresce under ultraviolet light and occasionally may resemble a budworm egg mass. However, the penlight was not used to search the foliage.

For the visible light examination, egg masses were counted in the same room with two 15-watt daylight lamps (F-15T8/D) mounted in each desk-type receptacle. The worktable was covered with white paper to provide contrast for the branches.

Measuring Efficiency

Each student examined 20 branches under each light source. Students 1 and 3 first used ultraviolet light and then, several days later, visible light. This sequence was reversed for students 2 and 4 to equalize experience. Separating the two examinations by several days reduced the ability of examiners to remember numbers of egg masses previously counted.

Initially, the maximum length and width of foliage on each branch were measured so that the foliated branch surface area examined by each student could be calculated (calculated by multiplying maximum length by maximum width and dividing by 2 (Mitchell 1974)). Then, each branch was clipped into small workable segments of 6 inches (ca. 15 cm) or less prior to examination. Any egg masses found were counted and left in place. Loose needles were also examined and placed in a box. These, together with all branch segments, were rebagged and returned to the cooler after each examination. The time required to examine foliage for egg masses was recorded for each branch.

Measuring Accuracy

Each student examined 10 heavily infested branches under each light source. Students 1 and 3 first used ultraviolet and then visible light, whereas students 2 and 4 reversed this order. As each branch was searched, all egg masses found were removed and stored in pill boxes labeled as to light source and sequence. The egg masses in each pill box were then examined, counted, and classified by the authors.

Characterizing Egg Masses

Egg masses found and removed under the second light source of each sequence were used to characterize those most likely to be missed under the first light source. Masses were examined with a stereomicroscope and classed as old or new, using criteria established by Buffam and Carolin (1966) and McKnight et al. (1970). Each class was then subdivided into normal or parasitized. Masses less than 50 percent parasitized were treated as normal. The number of egg masses for each class was recorded by light source.

Safety Considerations

The F-15T8/BLB black-light lamps used in this study emit longwave ultraviolet radiations ranging from 310–500 nanometers (nm), with a peak wavelength of 365 nm. Exposure to longwave ultraviolet radiations apparently does not cause skin damage.[4] Ultraviolet radiations below 320 nm cause skin reddening and sunburn, but these wavelengths amount to only 0.3 $\mu W/cm^2$ at 1 foot (ca. 30 cm) from a F-15T8/BLB lamp.[4] With two lamps at this distance, 7½ hours of continuous exposure would be required to develop a minimum perceptible reddening on previously untanned skin.[4] Any normally produced skin pigmentation, or pigmentation augmented by solar exposure, would provide enough skin protection to require a severalfold dosage increase before any noticeable reddening would develop. The students were exposed to the F-15T8/BLB lamps for a maximum of 6 hours during the study.

Results

Measuring Efficiency

The mean examination time required to locate egg masses (minutes per egg mass) on twenty

[3] *Trade and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

[4] *Personal communication with I. Matelsky, Environmental Control Operation Manager, Light Research and Technical Services Operation, General Electric Company, Nela Park, Cleveland, Ohio.*

24-inch (ca. 60 cm) Douglas-fir branches, compared for each light source by analysis of variance was:

Student	Mean foliated surface area		Ultraviolet light	Visible light
	in²	*(cm²)*	*min/egg mass*	
1	190.6	(1229.7)	0.96	1.44
2	210.4	(1357.4)	1.03	2.52
3	179.9	(1160.6)	1.10	1.85
4	169.1	(1091.0)	1.52	3.21
Mean			1.15	2.26

The mean time required per egg mass for all examiners was significantly less ($P < .05$) under ultraviolet light (1.15 min) than visible light (2.26 min). Mean examination time per egg mass was 48 percent faster using ultraviolet light. The mean foliated surface area examined did not differ significantly ($P < .05$) among the students.

Measuring Accuracy

The proportion of egg masses found during the first examination was significantly higher ($P < .05$) under ultraviolet light:

Examination	Egg masses found under— Ultraviolet–visible	Visible–ultraviolet
	Number	
First	476	402
Second	28	151
Total	504	553

During the first examination, only 72.7 percent of the total egg masses present were found with visible light, compared to 94.4 percent with ultraviolet light.

Characterizing Egg Masses

Invariably, some egg masses were missed during the first examination, regardless of light source. Eighty-nine percent of the egg masses missed under ultraviolet light were classed as old or parasitized, whereas only 58 percent of those missed under visible light fell into these classes:

Egg mass class	Egg masses missed under— Ultraviolet	Visible
	Number	
New:		
Normal	3	64
Parasitized	0	0
Old:		
Normal	21	87
Parasitized	4	0
Total	28	151

Forty-two percent of the egg masses missed under visible light were new. These represented about 12 percent of the total egg masses actually present on the visible-light sample.

Conclusions

Searching small Douglas-fir branches for western spruce budworm egg masses took 48 percent less time per egg mass with longwave ultraviolet light than with visible light. Ultraviolet light also increased the number of egg masses found by 22 percent over visible light. Thus, ultraviolet light increased both the efficiency and accuracy of locating egg masses on Douglas-fir foliage.

Some egg masses were not located under either light source. The few missed under ultraviolet light were mostly old, parasitized masses, but almost half of those missed under visible light were new. The new egg masses missed under visible light constituted about 12 percent of the total egg masses present on the foliage. The failure to detect new egg masses with visible light should be recognized as a possible source of error in sampling procedures such as McKnight et al. (1970), which use new egg masses to predict defoliation the following year.

Literature Cited

Buffam, Paul E., and V. M. Carolin, Jr.
1966. Determining trends in western spruce budworm egg populations. J. Econ. Entomol. 59(6):1442-1444.

Jennings, Daniel T.
1968. Using black light to find jack-pine budworm egg masses. USDA For. Serv. Res. Note NC-56, 3 p. North Cent. For. Exp. Stn., St. Paul, Minn.

McKnight, M. E., John F. Chansler, Donn B. Cahill, and Harold W. Flake, Jr.
1970. Sequential plan for western budworm egg mass surveys in the central and southern Rocky Mountains. USDA For. Serv. Res. Note RM-174, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Mitchell, R. G.
1974. Estimation of needle populations on young, open-grown Douglas-fir by regression and life table analysis. USDA For. Serv. Res. Note PNW-181, 14 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

CAUTION: Follow the manufacturer's recommendations when using ultraviolet light. Longwave (F-15T8/BLB) lamps emit a small amount of shortwave light, which is hazardous. These lamps pose no known safety hazard to workers with normal skin pigmentation. As a precaution, however, ordinary window glass can be taped beneath these lamps to screen out all shortwave light.

Agriculture—CSU, Fort Collins

April 1976

USDA FOREST SERVICE
RESEARCH NOTE RM-314

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Understory Production Not Predictable From Aspen Basal Area or Density

Kieth E. Severson and Jeremiah J. Kranz[1]

Analysis of effects of aspen basal area and density on production of understory vegetation revealed no useful predictive relationships using the model log Y = a + bX. However, as the proportion of ponderosa pine basal area increased in aspen-pine stands, understory production declined in a predictable manner. Root biomass, total biomass, and/or growth rate of aspen may be more closely related to understory production than measures of aspen overstory.

Keywords: *Populus tremuloides*, understory-overstory relationships, wildlife habitat.

Stands of quaking aspen (*Populus tremuloides*) have been recognized as an important habitat component for wildlife as well as valuable forage for livestock in the Black Hills and adjacent Bear Lodge Mountains. Increased emphasis is being placed on intensive management of aspen stands, particularly for ruffed grouse (*Bonasa umbellus*) and white-tailed deer (*Odocoileus virginianus*).

However, resource managers need more knowledge of the aspen complex to effectively manage for maximum ecosystem output. We tested Black Hills aspen data to determine if understory production could be predicted from selected attributes of the aspen overstory. This Note describes our efforts.

Previous Work

Most studies relating overstory crown cover or basal area to understory have revealed that understory forage production decreases as crown cover or basal area increases. Examples include Pase (1958) in Black Hills ponderosa pine, Ehrenreich and Crosby (1960) in hardwood stands in Missouri, Halls and Schuster (1965) in pine-hardwood forests in Texas, and McConnell and Smith (1970) in ponderosa pine in Washington. These researchers developed mathematical models that permitted resource managers to predict forage yields when overstory parameters were known. Jameson (1967) stated that inverse relationships found in such studies were reasonable because of competition for water, light, and nutrients.

When Harper (1973) worked in aspen forests of central Utah, he discovered that tree basal area was not correlated with annual production of the understory when aspen was the only tree present. If conifers were mixed with aspen, however, understory production declined rapidly as tree basal area increased. He attributed this decline to the influence of conifers.

Ellison and Houston (1958), while not attempting to relate overstory-understory attributes, did compare production of herbaceous vegetation under aspen and in adjacent openings. They also studied the differences between trenched (to remove competition from aspen roots) and untrenched plots under aspen. They found that openings adjacent to aspen stands produced more than untrenched plots under aspen, but that growth on trenched plots exceeded or equaled that in openings.

[1]*Severson is a Range Scientist, located at the Station's Research Work Unit at Rapid City; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Kranz is a Research Biologist with the South Dakota Department of Game, Fish and Parks, Rapid City.*

What We Did

We randomly placed twelve 100- by 100-foot macroplots in representative aspen stands. These plots were fenced to include a 25-foot buffer strip on each side. Diameter at breast height (d.b.h.) was measured on every tree within each macroplot. Stand attributes calculated were basal area (ft^2/acre) and density (stems/acre).

We estimated understory production in late August 1972 and 1973, using a double sampling procedure and ratio estimators as described by Blair (1958). Sixty 1- by 2-foot plots were randomly placed within each macroplot. Weights on these small plots were estimated and corrected to an ovendry basis.

Data were tested using the regression analysis model $\log Y = a + bX$; overstory attributes were considered the independent variables (X) and production of understory components the dependent variables (Y). All statistical tests were made at the $P = 0.05$ level.

What We Found

Overstory characteristics and understory production, by forage class for each of 2 years, are listed by stand in table 1. D.b.h. was measured at the end of the 1972 growing season, and it was assumed no major increments were added in 1973. Therefore, the same overstory data were used over both years.

Growing season precipitation (April through August) between the 2 years was variable over the Hills region, but was generally lower in 1973. April-August precipitation was 16, 27, and 37 percent less in 1973 than in 1972 at Sundance, Wyoming, and Deadwood and Spearfish, South Dakota, respectively, but was 11 percent higher at Deerfield, South Dakota. Total forage production was significantly lower in 1973, although decreases in individual classes—shrubs, forbs, and graminoids—were not significant.

No significant correlation coefficients (r) were observed when we used basal area as the independent variable. Additionally, of the eight tests made with basal area (production of shrubs, forbs, graminoids, and total for each of 2 years) four demonstrated a positive relationship and four were negative. Coefficients of determination (r^2) indicated that basal area in the model accounted for less than 30 percent of the variation.

Density of aspen stems had no significant effects in five tests. A positive correlation between aspen density and shrub production ($r = 0.68$, 1972; and 0.62, 1973) was significant. However, the resulting equations accounted for less than 50 percent of the variation in both cases.

Forb production demonstrated a significant negative correlation ($r = -0.74$) with aspen density, but only for data collected in 1973, the drier year.

Conifer reproduction in the 12 study areas was insignificant, and the influence of invading ponderosa pine (*Pinus ponderosa*) could not be evaluated. However, using data presented by Kranz and Linder (1973) for Black Hills aspen-ponderosa pine communities, we found that aspen basal area accounted for only 41 percent of the variation in understory production (positive correlation, $r = 0.64$). Pine and total basal area, in contrast, were useful predictors of total understory production in the equations $\log Y = 2.835 - 0.0027X$, when X = pine basal area; and $\log Y = 3.235 - 0.0050X$, when X = total basal area (pine and aspen). Correlation coefficients for the two relationships were -0.87 and -0.95, respectively.

Our Interpretation

We found no useful relationships between understory production and basal area or density of aspen. No prediction equations could be developed using the model $\log Y = a + bX$. Although other models are available, examination of the data in table 1 indicates they would probably yield similar results. As coniferous species invade, however, understory production declines in a predictable manner related to both increasing basal area of pine and total basal area. This is consistent with information reported by Harper (1973) for aspen in the mountains of central Utah.

Data collected for this study were insufficient to explain why understory production was not related to these aspen characteristics. This phenomenon is interesting, however, particularly when similar studies in both hardwood and conifer types have indicated a predictable relationship. Aspen has two somewhat unique characteristics that could help explain why such relationships are not apparent. This species reproduces primarily by sprouting from lateral root systems. Secondly, the aspen community is generally regarded as a seral stage preceding a climax coniferous stand. Rates of succession, however, vary considerably. Certain aspen stands are so stable that some investigators regard them as climax (Reed 1971, Wirsing 1973). If the seral stage is measured in terms of conifer invasion, the problem of predicting understory production becomes less acute. If conifer invasion is negligible, as in the climax *Populus tremuloides-Symphoricarpos orephilus* association described by Reed (1971) or in younger seral stands that have not been invaded by conifers, other parameters must be considered as independent variables.

Studies by Ellison and Houston (1958) of production on trenched and untrenched plots in aspen stands have indicated that aspen root systems do have a significant influence on understory growth. If an existing aspen stand is destroyed (by fire, cutting, or disease) a new stand can regenerate from the existing root system. Such stands, after suffering one or

Table 1.--Per-acre comparison of understory production with basal area and density of aspen on 12 quaking aspen areas in the Black Hills and Bear Lodge Mountains, 1972 and 1973

Aspen stand	Aspen overstory, 1972-73		Understory production, 1972				Understory production, 1973			
	Basal area	Density	Shrubs	Forbs	Graminoids	Total	Shrubs	Forbs	Graminoids	Total
	Ft^2/acre	*Stems/acre*	- - - - - - - - - - - - - - - -			*Lb/acre*	- - - - - - - - - - - - - - - -			
1	120	1429	266	353	390	1009	137	187	342	666
2	116	553	159	335	208	702	85	291	171	547
3	106	1115	271	149	59	479	359	252	121	732
4	104	815	152	246	110	508	116	236	170	522
5	96	1403	67	485	532	1084	73	164	475	712
6	94	3925	466	160	228	854	510	109	193	812
7	84	1477	330	86	107	523	522	135	72	729
8	83	1581	104	358	724	1186	84	283	307	674
9	82	2962	486	262	98	846	420	129	113	662
10	75	1673	147	490	557	1194	76	382	421	870
11	50	2365	374	171	184	729	228	102	149	479
12	42	3197	507	125	103	735	347	82	74	503

several perturbations, would have root systems considerably different from stands that had not been disturbed. It would be hypothetically possible to find stands of equal basal area or density originating from completely different root systems. A more complex, extensive root system may result in a more actively growing stand that removes more moisture and nutrients from the soil, thus competing with understory plants to a greater degree.

The several studies we reviewed made no mention of grouping sampled areas according to similar site characteristics before analysis. Site attributes were described only in general terms for the entire study area. In these studies, high correlation between overstory parameters and understory production apparently obviated the need for such grouping.

This led us to make the initial assumption that, although site differences influence total productivity, they do not necessarily influence the relationships between overstory and understory. Thus, we made no effort to select similar aspen sites for this analysis, and intentionally included different kinds of aspen stands. Therefore we must admit that we might have found higher correlations had we grouped aspen stands with similar site characteristics.

Root biomass, total biomass, and/or growth rate of aspen as affected by number of perturbations, seral stage, age of stand, and site characteristics may be more closely related to understory production than density and basal area of the existing aspen overstory. Such parameters would be difficult to measure, however, and their usefulness for management is therefore limited.

Literature Cited

Blair, Robert M.
1958. Weight techniques for measuring browse production on deer ranges, p. 26-31. **In** Techniques and methods of measuring understory vegetation. U.S. Dep. Agric., For. Serv., Southern For. Exp. Stn., New Orleans, La. 174 p.

Ehrenreich, John H., and John S. Crosby.
1960. Herbage production is related to hardwood crown cover. J. For. 58(7):564-565.

Ellison, Lincoln, and Walter R. Houston.
1958. Production of herbaceous vegetation in openings and under canopies of western aspen. Ecology 39(2):337-345.

Halls, Lowell K., and Joseph L. Schuster.
1965. Tree-herbage relations in pine-hardwood forests of Texas. J. For. 63(4):282-283.

Harper, K. T.
1973. The influence of tree overstory on understory production and composition in aspen forests of central Utah. Soc. Range Manage. [Boise, Idaho, Feb. 1973] Abstr. of Pap. 26:22.

Jameson, Donald A.
1967. The relationship of tree overstory and herbaceous understory vegetation. J. Range Manage. 20(4):247-249.

Kranz, Jeremiah H., and Raymond L. Linder.
1973. Value of Black Hills forest communities to deer and cattle. J. Range Manage. 26(4):263-265.

McConnell, Burt R., and Justin G. Smith.
1970. Response of understory vegetation to ponderosa pine thinning in eastern Washington. J. Range Manage. 11(5):208-212.

Pase, Charles P.
1958. Herbage production and composition under immature ponderosa pine stands in the Black Hills. J. Range Manage. 11(5):238-243.

Reed, Robert M.
1971. Aspen forests of the Wind River Mountains, Wyoming. Am. Midl. Nat. 86(2):327-343.

Wirsing, John M.
1973. Forest vegetation in southeastern Wyoming. M.S. Thesis, Wash. State Univ., Pullman. 170 p.

Agriculture—CSU, Fort Collins

ust 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-315

OREST SERVICE
J.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Dispersing *Bacillus thuringiensis* for Control of Cankerworm in Shelterbelts[1]

R. D. Frye, T. L. Elichuk, and John D. Stein[2]

A hydraulic sprayer and a cold fogger were equally effective for dispersal of the entomogenous bacterium *Bacillus thuringiensis* Berliner in shelterbelts. Pyrocide (pyrethrum) and Dimilin (a growth regulator) in combination with or without the bacterium provided the greatest cankerworm mortality in the belts.

Keywords: *Bacillus thuringiensis,* insect control.

The spring cankerworm, *Paleacrita vernata* (Peck), and the fall cankerworm, *Alsophila pometaria* (Harr), are important defoliators in shelterbelts in the northern Great Plains. In recent years, *P. vernata* has been the dominant species. Because they seldom kill trees, cankerworms are not considered a major forest pest. However, severely defoliated shelterbelts do not protect adjacent crops from severe weather stresses, and are esthetically unpleasing as well.

Concern over the use of conventional insecticides dictates that other types of control, including biological agents, be investigated. In a recent review, Harper (1974) indicated that 4 International Units[3] per acre of the entomogenous bacterium *Bacillus thuringiensis* Berliner effectively reduced cankerworm populations. Falcon et al. (1974) concluded that vertical coverage of cotton plants was more effective when *B. thuringiensis* was applied from the ground with a cold fogger than when the bacterium was applied from the air.

In 1975 we evaluated the effectiveness of ground-based fogging equipment for dispersing the bacterium in shelterbelts, and the bacterium in combination with other nonconventional insecticides. The study, conducted near Walhalla in Pembina County, North Dakota, was a cooperative effort involving North Dakota State University and the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

[1] *Published with the approval of the Director, North Dakota Agricultural Experiment Station as Publication No. 673.*

[2] *Frye is Prof. Entomol., and Elichuk is a graduate research assistant in entomology at N.D. State Univ., Fargo. Stein was Assoc. Entomol., Rocky Mt. For. and Range Exp. Stn., USDA For. Serv., Bottineau, N.D. in cooperation with N.D. State Univ., Bottineau Branch, when research was conducted. He is now with Pacific Southwest For. and Range Exp. Stn., Inst. of Pac. Islands For., Honolulu, Hawaii.*

[3] *An International Unit is defined as 1000 times the amount of a standard* B. thuringiensis *preparation required to kill 50 percent of the test larvae (usually the cabbage looper,* Trichoplusia ni*) in a laboratory assay, divided by the amount of the test material required to kill 50 percent of a group of similar larvae (Burges 1967).*

Methods and Materials[4]

The study was conducted in six Siberian elm (*Ulmus pumila* L.) shelterbelts. The belts, approximately 0.805 km long and 10.7 m tall, were utilized as blocks. Nine, 10-tree plots, 15.2 m apart, were marked in each belt. Treatments were randomized in each belt.

Larvae were counted on twigs approximately 0.5 m long before and after spraying. Twigs were cut from four sampling sites in each of two trees in each plot on May 28 and June 9, 1975. Two sites were located approximately 6.1 meters from ground level, one on each side of the crown; two sites were located at eye level, one on each side of the crown. Larval density per 100 Siberian elm leaves was determined for each plot and was based on the equation $Y = 763.1\ X^2$ where Y is the number of leaves per one-half meter twig, and X is the twig diameter in centimeters. Eighty-nine percent of the variation in the number of leaves was due to twig diameter. Mortality of cankerworm larvae was based on larvae per 100 leaves. Counts from the two trees were averaged by site for analytical purposes.

A test utilizing a known number of cankerworms was conducted to compare the effectiveness of the equipment described below for applying *B. thuringiensis* to shelterbelts. Sleeve cages (0.3048 m by 0.762 m) constructed from 22 mesh (22 openings/2.54 centimeters) Lumite screen (fig. 1) were placed over 1 branch in each plot (a total of 24 cages) to which *B. thuringiensis* was applied with different types of equipment and in untreated check plots immediately following application. Twenty-five third-instar larvae were placed on the foliage in each cage.

Nonconventional insecticides used in the investigation included Thuricide 16B (*B. thuringiensis*), Pyrocide (pyrethrum), and Dimilin (the growth regulator TH 6040). The materials were applied June 3,

[4] *The use of trade names is for brevity and specificity, and does not imply endorsement by the U.S. Department of Agriculture or North Dakota State University to the exclusion of other equivalent products.*

Figure 1.—Sleeve cage (0.3048 by 0.762 cm) used to isolate 25 third instar cankerworm larvae on Siberian elm foliage in a control test.

1975, at the following rates per acre: Thuricide 16B at 0.946 liter of product (4.0 billion I.U.), Pyrocide at 0.946 liter of product, and Dimilin 2E at 0.113 kilogram actual insecticide. When insecticides were combined in a treatment they were used at the same rates. The insecticides were applied with a cold fogger (Microgen M52W-15), a thermal fogger (Dyna Fog Model 70B) (fig. 2) and a hydraulic sprayer (Spartan). Each type of equipment was calibrated to determine the time required to apply specific amounts of insecticide to a known volume of foliage. The crown volume was determined by a method described by Stein and Doran (1975). Insecticides were applied from a pickup truck driven at a constant speed of 4.83 km/hr. Equivalents of approximately 18.87 and 2.83 liters of spray per acre were applied with the hydraulic sprayer and foggers, respectively.

Dispersal and survival of *B. thuringiensis* spores were determined from five 0.3167 cm^2 leaf samples by means of a serial dilution technique. Leaf samples were collected on June 4, 1975, 24 hours after application of the bacterium. The samples were placed in 10 ml of sterile, distilled water and shaken in a vortex mixer for 15 seconds. Serial dilutions were prepared in sterile, distilled water and spread-plated in replicate on five plates of plate count agar (Difco). Plates were incubated at room temperature. Average counts of viable spores from the replicates were recorded. Samples were collected from three sites (approximately 1.83, 3.66, and 6.1 m above ground) from the spray side of a single tree in each plot treated with *B. thuringiensis*. The samples were stored in coolers prior to processing. Results were subjected to analyses of variance, range tests (Duncan 1955), and regression analysis.

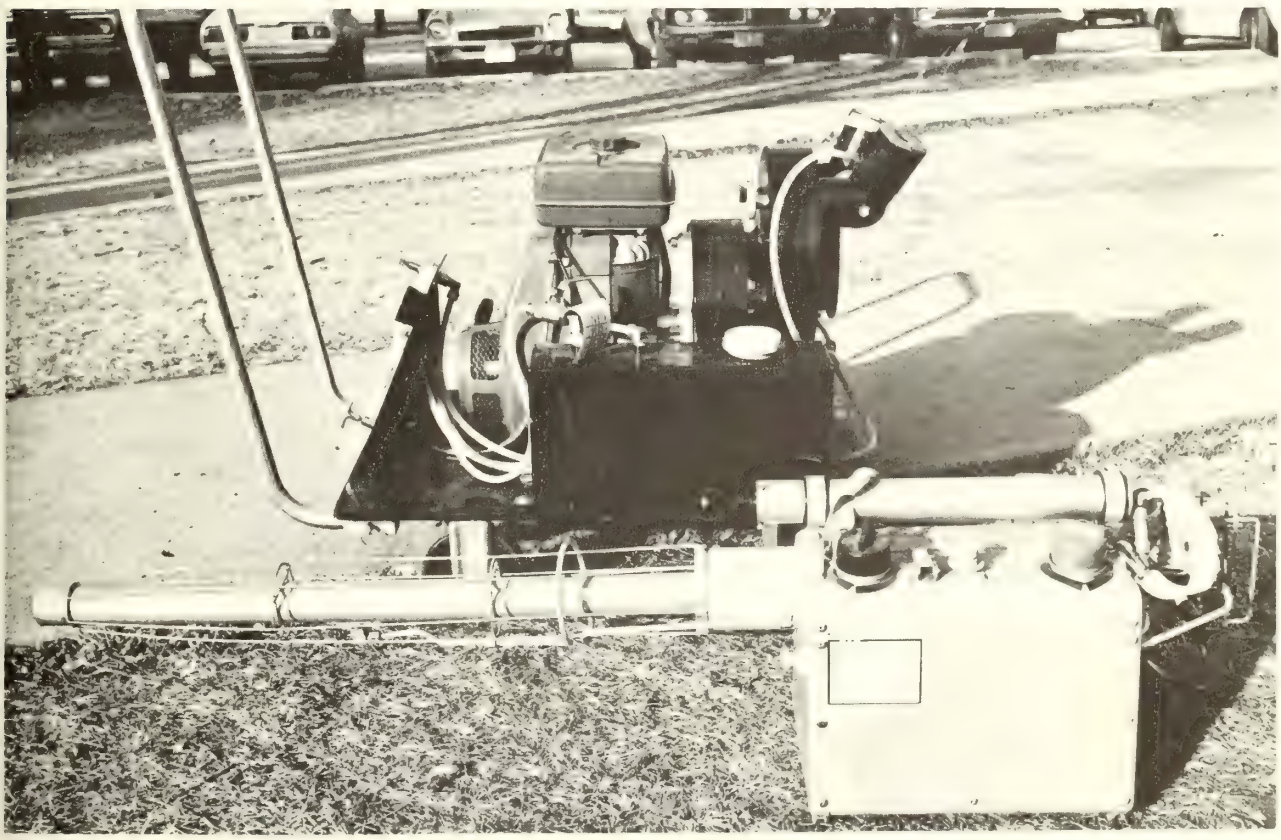


Figure 2.—Cold fogger (rear) and thermal fogger (front) used to apply *Bacillus thuringiensis*.

Results and Discussion

Differences in cankerworm populations among belts and sampling sites in trees prior to treatment were highly significant (table 1). Early instar larval density was greater in the top half of the trees (sites 1 and 2).

There were no significant differences in cankerworm numbers among treatment plots in the belts, and interaction between plots and sample sites was negligible.

Mortality of cankerworms exposed to *B. thuringiensis* and other insecticides varied with the types of equipment and combinations of insecticides used (table 2).

In the top half, spray side (site 1), pyrethrum plus *B. thuringiensis* and Dimilin plus *B. thuringiensis* applied with the hydraulic sprayer killed the most cankerworms (87 percent in both cases). In the top half, lee side of the tree (site 2), pyrethrum and pyrethrum plus *B. thuringiensis* applied with the hydraulic sprayer were the most effective (97 and 87 percent mortality, respectively). Pyrethrum plus *B. thuringiensis* applied with the cold fogger were the most effective treatments at site 3 in the lower half, spray side of the tree (96 and 91 percent mortality, respectively). In the lower half, lee side of the tree (site 4) Dimilin plus pyrethrum applied with the hydraulic sprayer and *B. thuringiensis* applied with the cold fogger were the most effective (96 and 94 percent mortality, respectively). Overall pyrethum plus *B. thuringiensis,* Dimilin plus pyrethrum, *B. thuringiensis,* pyrethrum and Dimilin plus *B. thuringiensis* applied by the hydraulic sprayer were the most effective. *Bacillus thuringiensis* applied with the hydraulic sprayer and the foggers was also effective.

Reasons for improved cankerworm control with the combination treatments are not clear at this time. Possible explanations include increased efficacy due to additive effects of components, and/or protection of the bacterium by the other formulations. A comparison indicated that overall mortality in belt 1 was lower than in other belts.

Mortality of cankerworms on treated foliage under sleeve cages indicates that the hydraulic sprayer and cold fogger were equally effective for dispersing *B. thuringiensis* spores. The thermal fogger was not as effective (table 3).

Spore coverages for different types of application equipment, and for combinations of *B. thuringiensis* with pyrethrum and Dimilin are shown in table 4.

Coverage appears best when combinations of *B. thuringiensis* with pyrethrum and Dimilin were applied by hydraulic sprayer. Spore coverage was also good when *B. thuringiensis* alone was applied by cold fogger or hydraulic sprayer. Statistically, the first four treatments were the same. The thermal fogger gave the lightest coverage.

The relationship of cankerworm mortality to *B. thuringiensis* spore density on foliage was not as strong as expected. Only 9.5 percent of the variation of cankerworm mortality was due to variation in spore counts. Considerable rain fell within 24 hours after the bacterium was applied and periodically throughout the sampling period (June 4-July 9,

Table 1.--Mean number of cankerworm larvae per 0.5 m twig before application of insecticide in Siberian elm shelterbelts, Walhalla, North Dakota, 1975

Belts		Sites[1] in sample trees	
Number	Larvae[2]	Number	Larvae[2]
5	44.96 a	1	28.19 a
3	36.92 ab	3	26.92 ab
6	31.96 bc	4	22.32 b
2	27.42 c	2	21.94 b
4	19.68 d		
1	5.26 e		

[1]Sites 1 and 2 were approximately 6.1 meters from the ground, one on each side of the crown (spray and lee sides); sites 3 and 4 were at eye level, one on each side of the crown.

[2]Means followed by the same letter do not differ significantly at P = 0.05.

Table 2.--Mortality of cankerworms on Siberian elm foliage treated with *Bacillus thuringiensis* applied with several types of equipment and in combination with other insecticides, Walhalla, North Dakota, 1975

Treatment		Mean mortality[1]	Mean mortality[2]
Material(s)	Dispersal method		
		- - *percent* - -	
Dimilin + pyrethrum	Hydraulic sprayer	94 a	88
B. thuringiensis + pyrethrum	Hydraulic sprayer	93 a	87
Pyrethrum	Hydraulic sprayer	85 a	71
B. thuringiensis	Hydraulic sprayer	83 ab	67
B. thuringiensis + Dimilin	Hydraulic sprayer	80 ab	62
B. thuringiensis	Thermal fogger	78 ab	58
B. thuringiensis	Cold fogger	75 ab	53
Dimilin	Hydraulic sprayer	74 bc	50
Untreated		47 c	--

[1]Means followed by the same letter do not differ significantly at P = 0.05.

[2]Adjusted by Abbott's formula (Abbott 1925), for the untreated check.

Table 3.--Mortality of 25 caged cankerworm larvae placed on Siberian elm foliage after *Bacillus thuringiensis* treatment with several types of equipment, Walhalla, North Dakota, 1975

Application method	Mean mortality[1]	Adjusted mortality[2]
	- - - - - *percent* - - - - -	
Hydraulic sprayer	81.3 a	74
Cold fogger	80.0 a	72
Thermal fogger	66.7 b	54
Untreated check	27.3 c	--

[1]Means followed by the same letter do not differ significantly at P = 0.05.

[2]Adjusted by Abbott's formula (Abbott 1925) to determine mortality attributable for the untreated check.

Table 4.--Coverage of Siberian elm foliage with *Bacillus thuringiensis* spores applied with several types of equipment and in combination with other insecticides, Walhalla, North Dakota, 1975

Treatment		Mean spore count[1,2]
Material(s)	Dispersal method	
B. thuringiensis + pyrethrum	Hydraulic sprayer	1,731,667 a
B. thuringiensis + Dimilin	Hydraulic sprayer	1,582,222 a
B. thuringiensis	Hydraulic sprayer	1,170,689 a
B. thuringiensis	Cold fogger	1,160,589 ab
B. thuringiensis	Thermal fogger	556,033 b

[1]Based on five 0.3167 cm^2 samples of elm foliage from six replications per treatment.

[2]Means followed by the same letter do not differ significantly at P = 0.05.

1975). Windspeed was 4.83 to 8.05 km/hr. This weather is typical of early summer and control methods will have to adapt to it.

Buettner (1951) showed that the amount of ultraviolet radiation reaching the earth decreases as sky cover (clouds and haze) increases. Ultraviolet radiation inactivates bacterial spores. It is likely that weather conditions influenced treatment performance and spore populations on the foliage. Weather records from Walhalla are missing for the test period.

Survival of *B. thuringiensis* spores on Siberian elm foliage dropped rapidly during the first 48 hours (June 4-6) of exposure to weather (fig. 3). Inactivation continued into early July, followed by a stabilization of the decline in the number of viable spores. This is evidence that more susceptible spores were killed during the first 48 hours, and the spores remaining on the foliage after that period were more resistant to weather factors, especially ultraviolet radiation. Davis et al. (1968) described a logarithmic survival curve of microorganisms irradiated by ultraviolet light that tails off into a line whose slope corresponds to more resistant organisms. More sensitive organisms are inactivated first, and at the end only the most resistant survive. There were significant differences in spore survival associated with the treatments.

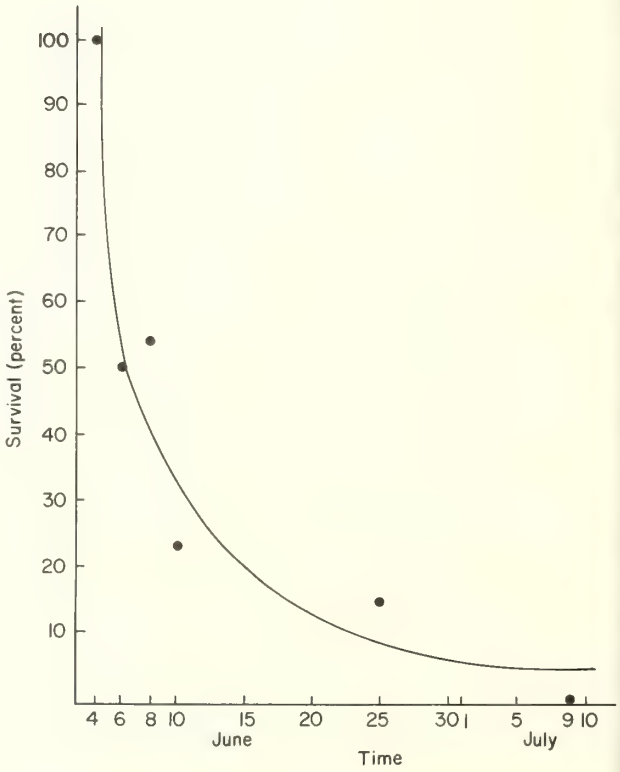


Figure 3.—Survival of *Bacillus thuringiensis* spores on Siberian elm foliage.

Summary and Conclusions

We evaluated the effectiveness of ground-based fogging equipment for dispersing the entomogenous bacterium *Bacillus thuringiensis* Berliner (in Thuricide 16B) for cankerworm control in Siberian elm shelterbelts. The bacterium was also tested in combination with other nonconventional insecticides. Both the spring cankerworm and the fall cankerworm were present in the plots near Walhalla, North Dakota.

Pyrocide (pyrethrum) plus Dimilin (a growth regulator) and *B. thuringiensis* plus pyrethrum applied with a hydraulic sprayer reduced cankerworm populations the most. Using a hydraulic sprayer to apply *B. thuringiensis* plus pyrethrum, or *B. thuringiensis* plus Dimilin, gave the best coverage of foliage with *B. thuringiensis* spores. The hydraulic sprayer and cold fogger both provided good dispersal of the bacterium when applied alone, and effectively controlled cankerworms.

When logistics are considered (amount of water needed, ease of handling), the cold fogger would be a good choice for applying the bacterium for cankerworm control in shelterbelts in the northern Great Plains.

There were no significant differences between treatments in survival of *B. thuringiensis* spores. Variability in the tests was rather high, except under controlled conditions where equal numbers of larvae (25) were used with all treatments.

Literature Cited

Abbott, W. S.
1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265-267.

Buettner, Konrad J. K.
1951. Physical aspects of human bioclimatology. p. 1112-1125. **In** Compendium of meteorology, Thomas F. Malone, ed. Am. Meteorol. Soc., Boston, Mass.

Burges, H. D.
1967. The standardization of products based on *Bacillus thuringiensis*. Proc. Intern. Colloq. Insect Pathology and Microbial Control, Wageningen, The Netherlands, 1966, P. A. van der Laan ed., North Holland Publ. Co., Amsterdam. p. 306-338.

Davis, B. D., R. Dulbecco, H. H. Eisen, H. S. Ginsberg, and W. B. Wood, Jr.
1968. Principles of microbiology and immunology. 853 p. Harper and Row, New York.

Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Falcon, L. A., A. Sorensen, and N. B. Akesson.
1974. Aerosol application of insect pathogens. Calif. Agric. 28:11-13.

Harper, J. D.
1974. Forest insect control with *Bacillus thuringiensis*—Survey of current knowledge, Auburn Univ. Press, Auburn, Alabama, 63 p.

Stein, John D., and D. J. Doran.
1975. A nondestructive method of whole tree sampling for spring cankerworm. USDA For. Serv. Res. Note RM-290, 4 p, Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.

st 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM 316

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The Influence of Supplemental Feed on Food Habits of Tamed Deer[1]

Wayne L. Regelin,[2] Richard M. Bartman,[3]
Donald W. Reichert,[2] and Paul H. Neil[3]

In a pinyon-juniper habitat, tamed mule deer with access to unlimited amounts of concentrate feed selected the same forage species in a similar proportion of their diet as deer that received no supplemental feed.

Keywords: Mule deer, food habits, *Odocoileus hemionus*.

The advantages and problems of observing tamed deer (*Odocoileus hemionus*) to acquire data on food habits are thoroughly discussed by Wallmo and Neff (1970). They surmise that tamed deer select the same forage species as their wild counterparts, a judgment based on experience observing both tamed and wild deer grazing, and on other empirical evidence provided by Buechner (1950), McMahon (1964), Watts (1964), and Healy (1967).

All of the available information on this subject supports the assumption that tamed and wild deer eat similar forage species, but the degree of similarity of the diets has never been quantified due to the difficulty of close observation of wild deer. Even if forage selection is an inherited characteristic, as Longhurst and others (1968) suggest, differences in the nutritional status of tamed and wild deer may still influence forage selections. Wild deer may be more selective than tamed deer because they must subsist entirely on native vegetation. In most food habits research using tamed deer, the animals have had access to supplemental feed before and after grazing trials. The purpose of this study, therefore, was to determine if the forage choices of tamed deer with access to unlimited concentrate feed between observations were different from those of tamed deer which subsisted entirely on native vegetation.

Study Area and Methods

All grazing observations were conducted in a 2-ha enclosure 5 km north of the Little Hills Game Experiment Station, 25 air km west of Meeker, Colorado. Vegetation in the enclosure was representative of one aspect of the pinyon-juniper-mountain browse community. The overstory consisted entirely of *Pinus edulis* and *Juniperus osteosperma*. Shrub species included *Amelanchier utahensis*, *Purshia tridentata*, *Symphoricarpos oreophilus*, *Artemisia tridentata*, and *Cercocarpus montanus*. The most prominent understory species were *Mertensia lanceolata*, *Sphaeralcea coccinia*, and *Lupinus caudatus*. No large herbivores had occupied the enclosure for the previous 7 years.

Six tamed mule deer fawns (approximately 5 months of age) were used in the study. These deer

[1]*Contribution of Federal Aid in Wildlife Restoration Project W-38-R.*

[2]*Regelin and Reichert are Range Scientist and Range Technician, respectively, Rocky Mountain Forest and Range Experiment Station with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

[3]*Bartman and Neil are Wildlife Researcher and Wildlife Technician, respectively, Colorado Division of Wildlife, Fort Collins.*

were hand-reared and trained at Fort Collins, Colorado, according to the procedures reported by Reichert (1972), and transported to Little Hills on September 21, 1975. The deer were randomly assigned to one of two treatments. Deer in the pasture treatment were placed in the enclosure on September 27, 3 days before grazing observation began, and remained in the pasture for the duration of the study without any supplemental feed. The three deer in the pen treatment were kept in a 30- by 30-m pen at the Little Hills headquarters, where they had access to unlimited concentrate feed and alfalfa. They were transported to the pasture for each grazing trial, and removed to the pen immediately after the trial.

Three observers ran simultaneous grazing trials for 10 consecutive days, beginning on September 30, 1975. A grazing trial is defined as one man following one deer for 1 to 2 hours and recording the number of bites by species eaten by that deer. Three trials were conducted in the morning and three in the afternoon for a total of 60 trials, or 10 per deer. Each deer was observed once daily, with the total observations equally divided between morning and afternoon periods. At the conclusion of all grazing trials, both the total number and the percentage of total bites for each plant species were tabulated by individual deer and for all deer in each treatment.

Results and Discussion

During all grazing trials, 46,103 bites were recorded; 48 species were eaten. The three deer in the pasture treatment took 27,538 bites of 46 different species, while pen-treatment deer consumed 18,565 bites of 39 species. Nine species were eaten by pasture-treatment deer that were not eaten by deer in the pen treatment. Pen-treatment deer grazed only two species which pasture-treatment deer did not eat. None of the species that were in the diet of only one treatment group comprised over 0.4 percent of the total bites, and most were incidental species (less than 15 bites taken). The average number of bites per grazing trial for deer in the pasture treatment was 918, and ranged from 257 to 1,448. Pen-treatment deer averaged 619 bites per trial, with a range of 200 to 1,060 bites. This differences was significant ($P<0.05$). All deer in both treatments consumed significantly more bites ($P<0.05$) during afternoon trials. Deer in the pasture treatment took 44.0 percent (range of 40.5 to 47.9) of observed total daily bites during morning trials and pen-treatment deer took 43.4 percent (range 41.6 to 43.8) of their bites during this time.

All species eaten and the percentage each comprised of the total bites taken by all deer and by deer in each treatment are shown below. Only nine species comprised 2.0 percent or more of the total bites by all deer and, together, they comprised 93 percent of all bites taken—90 percent for the pasture deer and 96 percent for the pen deer.

Species	All deer	Pasture deer	Pen deer
	(Percentage of total bites)		
Purshia tridentata	39.1	44.3	31.5
Amelanchier utahensis	17.2	10.6	27.0
Mertensia lanceolata	15.7	12.7	20.1
Symphoricarpos oreophilus	7.5	7.5	7.1
Cercocarpus montanus	4.1	4.1	4.2
Lupinus caudatus	2.3	3.5	.4
Cryptantha sericea	2.3	2.9	1.3
Sphaeralcea coccinea	2.2	2.7	1.4
Eriogonum umbellatum	2.1	1.6	2.9
Poa pratensis	1.2	2.0	[1]T
Penstemon caespitosus	1.1	.8	1.6
Physaria australis	1.1	1.6	.4
Aster leucanthemifolius	.5	.7	.3
Elymus cinereus	.5	.8	T
Oryzopsis hymenoides	.3	.4	.2
Artemisia tridentata	.3	.4	0
Penstemon fremontii	.2	.1	.3
Poa fendleriana	.2	.3	.1
Astragalus convallarius	.2	.3	T
Chrysothamnus nauseosus	.2	.2	.1
Descurainia richardsonii	.2	.3	T
Sitanion hystrix	.2	.2	T
Arabis holboellii	.1	.2	T
Senecio multilobatus	.1	.2	0
Bromus inermis	.1	.3	T
Senecio integerrimus	T	.1	T
Lithospermum ruderale	T	T	T
Carex species	T	T	T
Chenopodium fremontii	T	T	T
Pinus edulis	T	T	T
Balsamorhiza sagittata	T	T	T
Koeleria cristata	T	T	0
Chrysothamnus viscidiflorus	T	T	T
Senecio mutabilis	T	T	T
Streptanthus cordatus	T	T	T
Tragopogon dubius	T	T	T
Erigeron eatoni	T	T	T
Antennaria microphylla	T	T	T
Polygonum sawatchense	T	T	0
Agropyron inerme	T	T	T
Collinsia parviflora	T	T	T
Artemisia ludoviciana	T	T	0
Erysimum aspermum	T	0	T
Stipa comata	T	0	T
Phlox longifolia	T	T	0
Mushroom	T	T	T
Unidentifiable forb	T	T	T
Unidentifiable grass	T	T	T

[1]T = trace = <0.1

To determine if selection of these nine major forage species varied significantly between treatments, a profile analysis of variance for two groups over species was done. Two analyses were run, one on the percentage of total bites (with arcsine transformation), and the other on the number of bites of the nine major species eaten by each deer each day. The analyses produced nearly identical results, and did not change the significance level of any test. These analyses allowed a test of the diet variability between deer within the same treatment group, and a strong test of the treatment x species interaction, which was the major item of interest. The treatment effect was not significant ($P < 0.05$), indicating the three deer within each treatment selected the major forage species in similar proportions of their diet.

The treatment x species interaction was significant ($P < 0.05$), however. The data were graphed (fig. 1) to determine where the interaction occurred. The major difference between the two groups of deer was in the proportions of the three most prominent species in their diets. The deer in the pasture (no supplemental feed) ate more *Purshia tridentata* and less *Amelanchier utahensis* and *Mertensia lanceolata* than deer in the pen treatment. The proportions of the other major species were similar between the two treatments with the exception of *Lupinus caudatus*, of which deer in the pen treatment ate very little.

The composition of shrubs, forbs, and grasses in the diets of the deer in each treatment was similar. Shrubs comprised 67.1, forbs 28.6, and grasses 4.3 percent of the diet in the pasture treatment and 69.9, 29.5, and 0.6 in the pen treatment.

The intent of most food habits studies is to identify all forage species, and indicate those which are major components of the diet. This study demonstrated that tamed deer receiving supplemental feed select the same forage species in the bulk of their diet as deer subsisting on native forage.

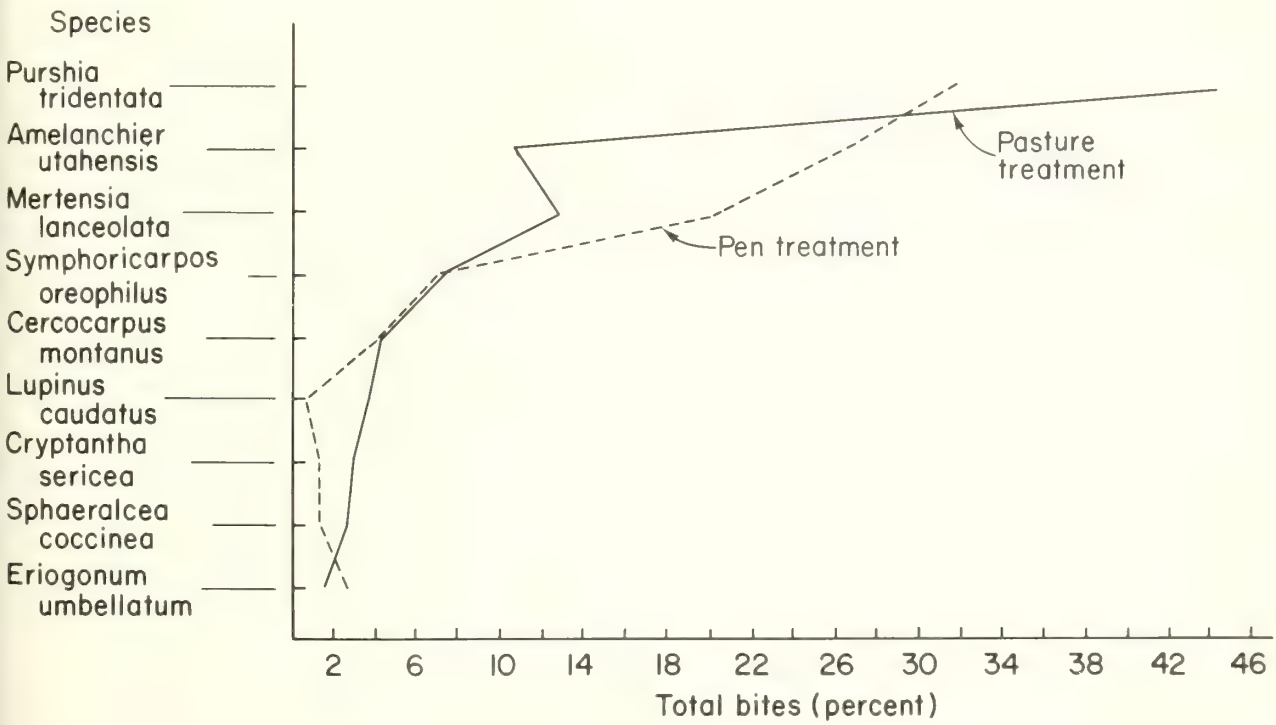


Figure 1.—Percentage of major diet components by pen and pasture treatments.

Literature Cited

Buechner, H. K.
1950. Life history, ecology and range use of the pronghorned antelope in Trans-Pecos, Texas. Am. Midland Natur. 43:257-354.

Healy, W. M.
1967. Forage preferences of captive deer while free ranging in the Allegheny National Forest. M.S. thesis. Pa. State Univ., Univ. Park, Pa., 93 p.

Longhurst, W. M., H. K. Oh, M. B. Jones, and R. E. Kepner.
1968. A basis for the palatability of deer forage plants. N. Am. Wildl. Conf. Proc. 33:181-192.

McMahon, C. A.
1964. Comparative food habits of deer and three classes of livestock, J. Wildl. Manage. 28:798-808.

Reichert, D. W.
1972. Rearing and training deer for food habits studies. USDA For. Serv. Res. Note RM-208, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Wallmo, O. C., and D. J. Neff.
1970. Direct observation of tamed deer to measure their consumption of natural forage. p. 105-110. **In** Range and Wildlife Habitat Evaluation—A Research Symposium. U.S. Dep. Agric., Misc. Publ. 1147, 220 p.

Watts, C. R.
1964. Forage preferences of captive deer while free ranging in a mixed oak forest. M.S. thesis. Pa. State Univ., Univ. Park, Pa. 65 p.

3.79 RM-317
t 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-317

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Cone Maturation in Ponderosa Pine Foliage Scorched by Wildfire

W. J. Rietveld[1]

Trees scorched to varying degrees were studied to determine the effects of a late fall wildfire on several cone and seed characteristics. While cone size, seed soundness, and seed weight were markedly less in severely scorched trees, trees with crowns scorched as much as two-thirds produced highly viable seed. Trees scorched more than two-thirds yielded small amounts of seed of dubious quality, and are poor survival risks. Seedfall from foliage-scorched trees represents a significant seed source for regeneration of burned areas.

Keywords: *Pinus ponderosa* var. *scopulorum,* fire, effect on seed production.

Foliage-scorched trees, as distinguished from trees where foliage was consumed, have reasonably good survival potential, depending on the time and intensity of the fire and the extent of scorching. Climatic conditions, the amount of photosynthetic tissue remaining and the capacity to generate new needle tissue, and resistance to insect attack will determine the ultimate survival of individual trees. But what becomes of conelets on the trees at the time of the fire? Will fertilization occur and seeds mature, or will the cones be abandoned in favor of higher priority recovery processes?

To answer these questions, several young cone-bearing ponderosa pines (*Pinus ponderosa* var. *scopulorum*) whose foliage was scorched in a fall wildfire were monitored to determine the relationship between extent of scorch and various cone and seed parameters.

[1]*Plant Physiologist, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Description of Fire

During November 2-7, 1973, the fast-spreading Burnt fire covered 7,150 acres on the Coconino National Forest, Arizona. The fire was of moderate intensity due to cool ambient air conditions (50°-60°F days, subfreezing nights) and resultant higher relative humidity and fuel moisture. Stocking and ground fuels were moderate but variable because some stands had been partially cut and precommercially thinned during the 10-year period prior to the fire. Tree damage ranged from light scorch (needles killed, but not consumed, by the fire) of lower crowns in light to moderately stocked areas, to complete needle consumption (needles completely burned off the tree) in more heavily stocked areas. Scorched needles and smaller branches were typically desiccated and stiffened horizontally in the direction of fire spread. Denser stands of trees which "crowned-out" were killed outright, many seedlings and saplings were either consumed or killed by direct heat damage to the cambium, and many trees subsequently died from excessive foliage-scorch.

During the summer of 1974 it was evident that many foliage-scorched trees were putting out vigorous new growth, and conelets that had been initiated the previous year were continuing to develop. The bright green new needles contrasted with the persistent brown, scorched needles.

Study Area and Methods

The study was established on site index 50 to 54 land (Minor 1964) at 7,400 feet elevation. Orion rocky sandy loam soils on the study area were derived from igneous parent materials. In September 1974, 10 months after the fire, 38 cone-bearing trees that ranged in size from 8.0 to 21.7 inches diameter at breast height (d.b.h.), and in age from 56 to approximately 150 years old were selected for study. Trees were tagged over approximately 100 acres of the burn. The degree of damage ranged from none (control) to 74 percent of the live crown scorched (table 1).

Table 1.--Cone and seed parameters of cone-bearing ponderosa pines foliage scorched to varying degrees, Coconino National Forest, Arizona. (Burnt fire, November 2-7, 1973; cone and seed data collected November 7, 1974)

Tree data				Cone and seed data				
Tree number	Diameter at breast height	Height	Portion of crown scorched	Cone size[1]	Mean seed weight	Mean seed soundness	Mean germination[2]	Mean time for 50 percent germination
	inches	*feet*	*percent*		*g*	*- - - percent - - -*		*days*
34	17.7	52.0	0	L	--	86.2	99.4	5.3
35	17.0	48.5	0	L	0.032	93.0	99.7	6.1
36	9.7	26.5	0	M	.027	95.8	99.8	6.4
37	17.8	42.5	0	L	.027	92.3	99.2	5.9
38	12.5	36.5	0	M	--	87.2	98.5	6.3
25	12.3	34.5	7	L	.029	90.0	99.1	6.1
26	9.5	24.0	8	M	.025	84.5	99.7	5.6
18	15.5	40.5	10	L	--	90.2	71.1	7.6
1	17.5	44.0	14	L	.026	87.0	99.4	5.4
3	13.2	31.0	16	M	.021	87.3	97.6	5.7
24	10.0	24.5	20	M	.033	83.3	98.8	5.7
20	14.9	39.5	21	M	.035	77.0	83.9	8.1
10	14.8	37.0	28	L	.045	60.0	98.0	5.8
19	13.5	33.5	30	L	.044	91.8	98.9	6.2
2	13.7	34.0	30	L	.039	94.8	99.7	5.7
28	13.3	41.0	32	M	.030	90.3	99.2	5.6
4	19.2	48.5	34	L	.051	68.0	99.7	6.0
9	16.7	42.0	35	M	.033	88.0	95.0	6.2
16	11.5	29.5	36	VS	.026	37.0	71.9	7.4
22	13.6	40.5	42	L	.038	92.4	100.0	5.7
31	11.6	38.5	46	S	.029	84.3	97.9	5.6
11	11.7	30.0	47	L	.056	77.0	98.1	6.0
7	13.2	31.5	47	M	.033	80.8	98.1	5.2
13	13.3	35.0	47	L	.044	87.5	96.0	6.1
17	8.4	26.0	48	VS	--	56.8	80.6	6.5
8	12.3	42.0	48	S	.021	44.0	90.1	5.4
21	14.4	40.0	48	L	.044	91.5	98.6	6.2
5	21.7	52.5	52	L	--	92.3	100.0	5.7
27	16.8	47.0	53	M	.041	93.0	99.5	6.7
23	11.9	30.5	54	L	.034	89.5	100.0	6.4
30	13.0	45.5	54	S	.028	33.8	87.5	6.7
29	12.2	32.0	57	S	.029	88.8	99.2	5.9
12	12.5	41.5	58	M	.034	93.8	97.9	5.5
33	11.1	33.5	60	M	.023	65.8	94.3	6.5
6	11.1	35.5	65	S	.021	85.0	99.7	5.5
32	10.4	38.0	67	S	.022	60.3	94.5	5.7
14	9.1	29.0	71	VS	.020	50.3	28.3	8.3
15	8.0	28.5	74	VS	.021	25.3	17.7	7.6

[1]L = large, M = medium, S = small, VS = very small. See figs. 1 and 2 for comparisons.
[2]Based on sound seed.

Approximately 12 cones were uniformly selected from the undamaged portion of the crown of each tree on November 7, 1974, when cones on some trees were beginning to open. Severely scorched trees yielded relatively few cones, while trees that suffered less damage provided many cones for samples. The late collection date allowed ample time for natural ripening of seed. Since cone size in some trees was clearly affected by the fire, cone volume was determined by water displacement. Seeds were extracted in a growth chamber set at 90°F and low humidity. After cleaning on a soil screen, 10 filled seeds from each of the 38 lots were weighed to the nearest 0.0001 gram to determine mean seed weight.

The seeds were stored in a freezer for 3 months before germination tests began. Each germination test consisted of four petri dishes containing 100 seeds each. The seeds were pressed into a bed of uniformly wetted Perlite, and incubated in a germinator set at 75°F and 95 percent relative humidity. Larson (1967) reported that germination of ponderosa pine seed was better at a constant 75°F than any alternating temperature. Germinated seeds (defined as when the radicle equaled the length of the seed) were removed from the petri dishes daily until no germination was recorded on two successive inspections. Ten germinants taken at random from each germination test were grown in styrofoam flats in a growth chamber for 1 month to detect any post-germination abnormalities in morphology or growth rate. At the conclusion of the germination tests (16 days' duration), ungerminated seeds were cut to determine soundness. Percentage germination was calculated on the basis of number of sound seeds. The mean number of days to reach 50 percent germination was also calculated to compare the rates of germination.

Results

Trees scorched as much as two-thirds produced cones that yielded highly viable seed (table 1, fig. 1). With the exception of five trees, all trees scorched 0 to 67 percent yielded filled seed with 90 percent germination or greater; only two trees, scorched 10 to 36 percent, yielded seed with germination less than 80 percent. The sample included only two trees with

Tree 8—scorched 48 percent

Tree 32—scorched 67 percent

Figure 1.—Both trees produced small cones that contained highly viable seeds with over 90 percent germination (filled seeds). Seed soundness and seed weight, however, were low. Photos were taken 1 year after the fire; scorched needles have fallen, but live foliage remains.

crowns scorched more than 70 percent; germination of filled seed from these trees, scorched 71 and 74 percent, was very low—only 28.3 and 17.7 percent, respectively. The plot of seed germination (fig. 2) suggests that germination of filled seed is little affected by foliage-scorch up to approximately 70 percent of the live crown, then declines abruptly. However, the sample did not include enough trees scorched more than 70 percent to clearly define this trend.

Rate of germination, measured by number of days to reach 50 percent germination (table 1), followed the same trend as percentage germination. Seed lots with over 90 percent germination varied in rate from 5.2 to 6.7 days, while the seven trees with less than 90 percent germination required 6.5 to 8.3 days. The two trees scorched 71 and 74 percent required 8.3 and 7.6 days, respectively—considerably longer than most of the other seed lots.

Seed soundness tended to decrease as the extent of foliage-scorch increased (table 1, fig. 2). However, two-thirds of the trees scorched up to 65 percent yielded over 80 percent filled seed.

Cone size varied only from large to medium in trees scorched up to 35 percent. In trees scorched more than 35 percent, cone size ranged from large to very small. Cones classed as small (S) and very small (VS) in table 1 were clearly retarded by the fire, and tended to be more prevalent as the degree of foliage-scorch increased. However, many diminutive cones yielded seeds with over 90 percent germination (fig. 3)—equal to seeds from larger cones and less severely damaged trees. The tiny cones from trees 14 and 15, which were most severely scorched, yielded seeds with low viability and soundness.

Seed weight varied directly with cone size (table 1). Large cones yielded filled seeds averaging 39 mg, compared to 30 mg for medium cones, and 24 mg for small and very small cones.

Two trees died during the period November 7, 1974, to September 9, 1975: tree number 3 from bark beetle attack, and tree number 17 from excessive heat damage to the cambium and foliage.

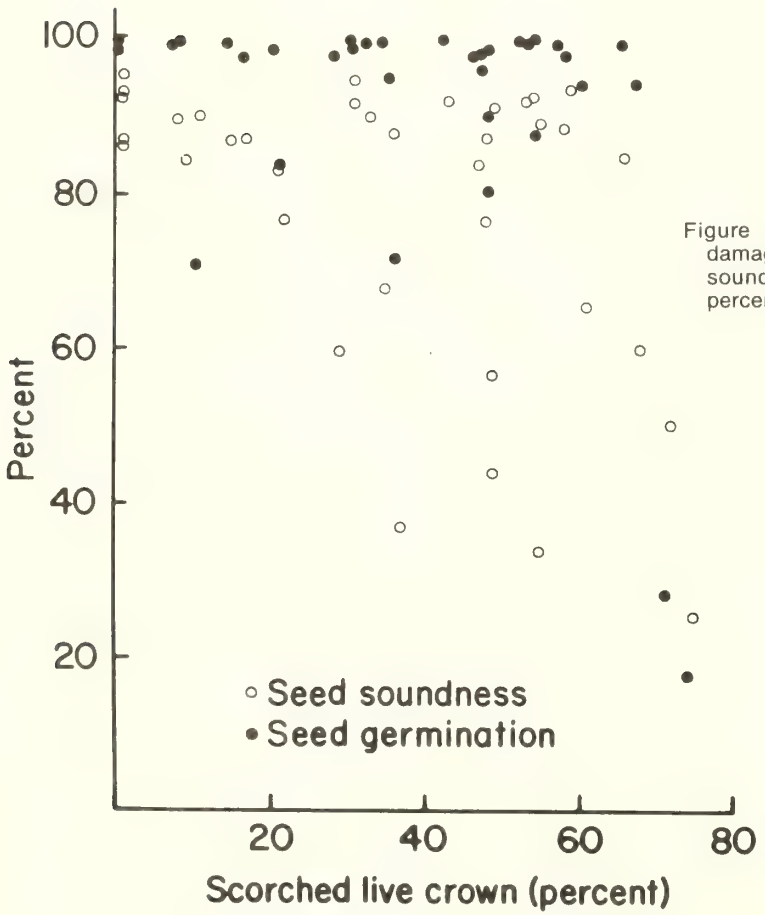
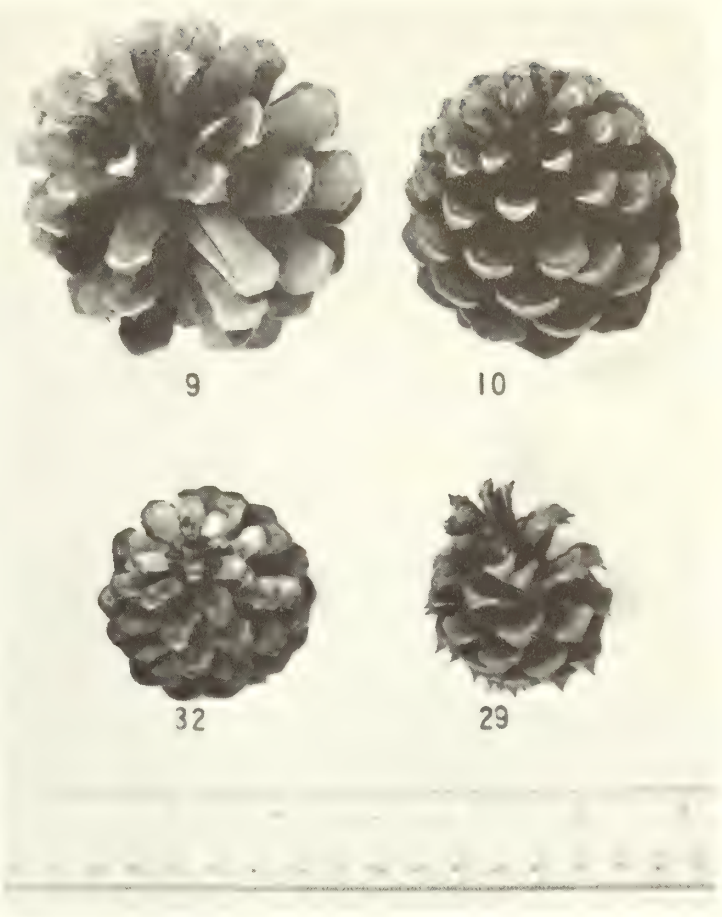


Figure 2.—Relationship between the extent of fire damage to cone-bearing trees and the germination and soundness of extracted seed at maturity. (Germination percentages are based on sound seed.)

Figure 3.—Comparison of cones from trees with varying percentages of scorch.

Cones show range in size of cones that yielded seeds with over 90 percent germination (filled seeds).



Tree 9—
35% scorch

Tree 10—
28% scorch

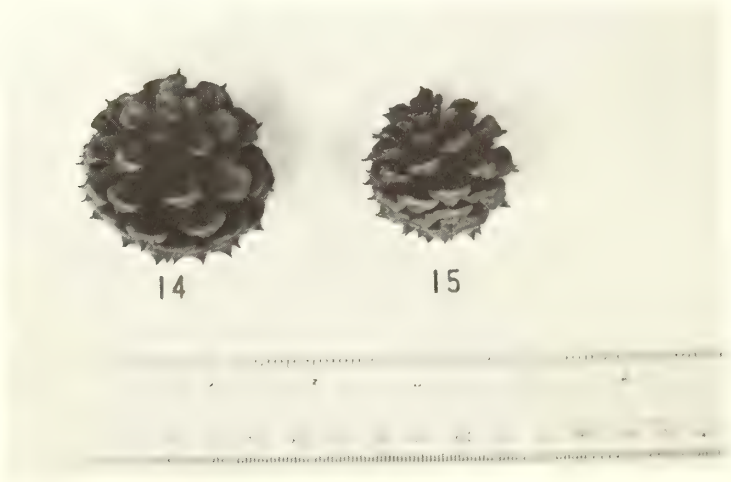
Tree 32—
67% scorch

Tree 29—
57% scorch

Tree 14—
71% scorch

Tree 15—
74% scorch

Cones from severely scorched trees were diminutive, and yielded seeds with low viability.



Discussion

Because each fire is unique, and fire intensity varies within each burn, assessing the extent of damage to individual trees is extremely difficult. The intensity of the burn, and timing of the burn in relation to the growth stage of the trees, will largely determine the amount of damage, and consequently the potential for recovery. A dormant-season fire is less damaging than one during spring and summer because of the coincidence with growth processes. In southwestern ponderosa pine, vegetative buds begin swelling as early as May 1 and shoot growth is complete by July 10. Diameter growth begins May 15 to 30, and ends sometime between September 1 and 20 (Schubert 1974). Generally, on burns during periods of minimum tree sensitivity, the potential for recovery of foliage-scorched trees and maturation of cones is good.

The results of this study show that even severely scorched trees are capable of producing viable seed. The Burnt fire occurred during the pollen-tube development stage of seed genesis; fertilization did not occur until July 1974, approximately 13 months after pollination (Krugman et al. 1974). The decrease in seed soundness and seed germination with increasing foliage-scorch could be due to heat damage to the developing pollen-tube apparatus or archegonia (multicellular sex organs within the ovule containing the egg nuclei). In trees producing diminutive cones, post-fertilization growth of the cone by cell enlargement apparently was reduced or prevented. Growth factors—including carbohydrates, nutrients, and water—were either unavailable, limited, or preferentially translocated to sites of higher priority. Thus, even in severely scorched trees, cone and seed development and maturation proceeded with only minimal amounts of needed growth factors. It appears, then, that the allocation of resources in fire-stressed ponderosa pines allows maturation of existing cones.

The average weight of filled seeds from large- and medium-sized cones was 35 mg, very close to the 37 mg reported by Larson and Schubert (1970). The small seeds extracted from diminutive cones (averaging 24 mg) are not necessarily inferior from a regeneration standpoint. Larson (1963) found that size of seed had little or no influence on rate of germination, germination percent, or seedling growth.

Seedfall from surviving foliage-scorched ponderosa pines represents an important seed source for regenerating the burn. Trees scorched less than approximately 35 percent are the best seed producers, both in quantity and quality. But more severely scorched trees, even those producing diminutive cones, are capable of contributing smaller amounts of highly viable seed. Trees with more than two-thirds of their crown scorched produce only a small number of cones and seed of dubious quality; they should not be relied upon as a seed source. Furthermore, Herman (1954) reported that trees with 60 percent or more crown kill have very low survival potential—3 percent after 6 years, compared with 86 percent survival of trees scorched less than 60 percent.

To create a favorable seedbed on burns, mechanical soil disturbance is needed in addition to the elimination of competing vegetation and baring of mineral soil by the fire (Rietveld and Heidmann 1976). Any fire-induced soil water repellency is broken up, and the reduction in soil bulk density reduces frost heaving of seedlings (Heidmann and Thorud 1975). Some soil disturbance is created by salvage logging; additional site preparation may be performed just prior to seedfall.

Literature Cited

Heidmann, L. J., and David B. Thorud.
1975. Effect of bulk density on frost heaving of six soils in Arizona. USDA For. Serv. Res. Note RM-293, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Herman, F. R.
1954. A guide for marking fire-damaged ponderosa pine in the southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 13, 4 p., Fort Collins, Colo.

Krugman, Stanley L., William I. Stein, and Daniel M. Schmitt.
1974. Seed biology. p. 5-40, **In** Seeds of Woody Plants in the United States. U.S. Dep. Agric., Agric. Handb. 450, 883 p. Wash., D.C.

Larson, M. M.
1963. Initial root development of ponderosa pine seedlings as related to germination date and size of seed. For. Sci. 9:456-460.

Larson, M. M.
1967. Effect of temperature on initial development of ponderosa pine seedlings from three sources. For. Sci. 13:286-294.

Larson, M. M., and Gilbert H. Schubert.
1970. Cone crops of ponderosa pine in central Arizona, including the influence of Abert squirrels. USDA For. Serv. Res. Pap. RM-58, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Minor, Charles O.
1964. Site index curves for young-growth ponderosa pine in northern Arizona. U.S. For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Rietveld, W. J., and L. J. Heidmann.
1976. Direct seeding ponderosa pine on recent burns in Arizona. USDA For. Serv. Res. Note RM-312, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Schubert, Gilbert H.
1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA For. Serv. Res. Pap. RM-153, 71 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Agriculture—CSU, Fort Collins

1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-318

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STA

Correlation Between Transmissivity and Basal Area in Arizona Ponderosa Pine Forests[1]

Rhey M. Solomon,[2] Peter F. Ffolliott,[3] and J. R. Thompson[4]

Transmissivity (portion of insolation incident upon forest canopy that is transmitted through the overstory to the snow surface) was empirically related to stand basal area of sample plots by a logarithmic transformation. Seasonal variation was not statistically significant.

Keywords: Basal area, insolation, transmissivity, *Pinus ponderosa*.

Introduction

Snowmelt is a major source of runoff to the reservoir system in central Arizona. More than 68 percent of the flow to the reservoir system may originate as snowmelt during the spring runoff period (Warskow 1971). Because snow contributes such a large proportion of the surface water in the State, it warrants intensive investigation and management.

Snowmelt is a dynamic process involving different energy transfers, and as such, must be assessed with changes in time. As a consequence, prediction of snowmelt is complex and involves the identification of many variables which themselves are continually changing. Primary sources of energy to melt snow are short- and long-wave radiation. Short-wave radiation incident upon the forest canopy can be affected by percent transmittance of insolation through the forest overstory, albedo of the snowpack, snowpack density, and depth, slope, and aspect.

Description of Study

Transmissivity is the primary variable controlling the amount of short- and long-wave radiation available at a snowpack's surface. Thus, if solar radiation measurements are to be used as the energy source for snowmelt prediction, a relationship between percent transmittance (that portion of insolation incident upon the forest canopy that is transmitted through the overstory to the snowpack) and a readily measured forest attribute must be identified. To this end, a study was initiated at Campbell Blue in east-central Arizona.

Study Area

The Campbell Blue area is located 7 miles south of Alpine on the Apache-Sitgreaves National Forest. A predominantly ponderosa pine forest, the site supports diverse forest cover densities ranging from open parks to dense stands. With a mean elevation of 8,000 feet, this gently rolling study area contains few slopes in excess of 15 percent, providing a suitable site for studying solar radiation transmissivity.

[1]*The work reported here was supported, in part, by funds provided by the U.S. Department of the Interior as authorized under the Water Resources Act of 1964, PL 88-379.*

[2]*Hydrologist, Gila National Forest, USDA Forest Service, Silver City, New Mexico; formerly Research Assistant, School of Renewable Natural Resources, University of Arizona, Tucson.*

[3]*Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson.*

[4]*Principal Meteorologist, Rocky Mountain Forest and Range Experiment Station, located at the Forest Hydrology Laboratory at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Methodology

The sample design consisted of three clusters containing five sample points per cluster forming a one-fifth-acre plot. Each cluster was designed in the shape of a diamond, with one point at the four corners of the diamond and the fifth point in the center 50 feet from each corner point. Because each point in a cluster represented a different forest condition, it could be treated as a discrete sampling point. This produced 15 different forest conditions in the sample, within the size classes present (large poles to small sawtimber).

Six solar pyranometers were used in the study: five were used to sample transmissivity, while the sixth, located in Alpine atop a mobile home, served as a control. Thus only one cluster was sampled per day. The sensors were rotated randomly every day among sample points.

Before sunrise of a sampling day, the sensors were mounted and leveled atop 3-foot wood stands located at each sampling point, then connected to digital integrators (Thompson and Ozment 1972) and hourly readings taken from sunrise to sunset. Only sunrise and sunset readings were recorded on days with extensive cloud cover. A total of 16 days of data were collected during periods of measurement, one in March and the second in June.

Forest overstory characteristics influence the amount of insolation transmitted through the overstory. Therefore, a measure of forest attributes might be used to index the amount of radiation incident upon the snowpack. Basal area and stem density were measured at each sample point by point-sampling techniques.

After field data were collected, the sensors were calibrated to standardize all records. Shading cloths of various transparencies were used to expose each sensor to different energy fluxes. One sensor was arbitrarily chosen as standard, and the other five were correlated with it by means of regression equations.

Once each sensor was calibrated to a standard scale, the next step was to transform all data to that same scale. It was assumed that radiation recorded by each sensor on clear days approximated a cosine curve. It was further assumed that this cosine curve could be approximated by two linear segments, one rising and one falling, to form a triangle. With these two assumptions, it was then possible to calculate an average langley value for the entire day, substitute this value into the corresponding regression equation, and arrive at the total standardized langleys for the particular sensor. This procedure was followed for all sensors on clear days. For cloudy days, the procedure was duplicated with the exception that only that part of the day with no cloud cover was considered as contributing significant flux differences between the opening and forested conditions.

The standardized daily insolations were then plotted and regressed against the forest attributes to establish any significance between variables.

Results and Discussion

Basal area and stem density proved significant as empirical indexes of transmissivity. However, the correlation coefficient of stem density versus transmissivity was only 0.50 compared with 0.83 for basal area; therefore, basal area was chosen as the predictor of transmissivity.

Since no significant difference existed between March and June transmissivities grouped by basal area, all data were combined in a plot of transmissivity values against basal area (fig. 1).

Transmissivity values on cloudless days were statistically identical with those values obtained on cloud-free portions of partially cloudy days. Transmissivity averages ranged between 40 and 55 percent on cloudy days, independent of basal area or season.

Previous work has indicated nonlinear relationships between transmissivity and forest attributes (Muller 1971, Reifsnyder and Lull 1965). An inspection of figure 1 suggests that a logarithmic transformation might be used to develop a regression equation. With such a transformation, the following equation, with a correlation coefficient of 0.794, resulted:

$$\log (TR) = 2.144 - 0.229 \log BA$$

where

TR = transmissivity in percent, and
BA = basal area in ft^2 per acre.

It should be emphasized that the range of basal area values was 25 ft^2 per acre to 125 ft^2 per acre within the size classes present, and that extrapolation beyond those limits might not be justified. However, on the lower end we know that zero basal area would be 100 percent transmissivity.

Conclusions

Because the primary concern in this study was the determination of average transmissivities during the snowmelt season, no attempt was made to assess diurnal variation in this factor. Measurements made in March and June were not significantly different; thus, a combined equation for estimating the snowmelt-season transmissivity was possible.

The relationship between basal area and transmissivity proved to be curvilinear; therefore, a logarithmic transformation was used in the final regression analyses.

Cloudy-day transmissivities were not related to basal area or season (sun angle).

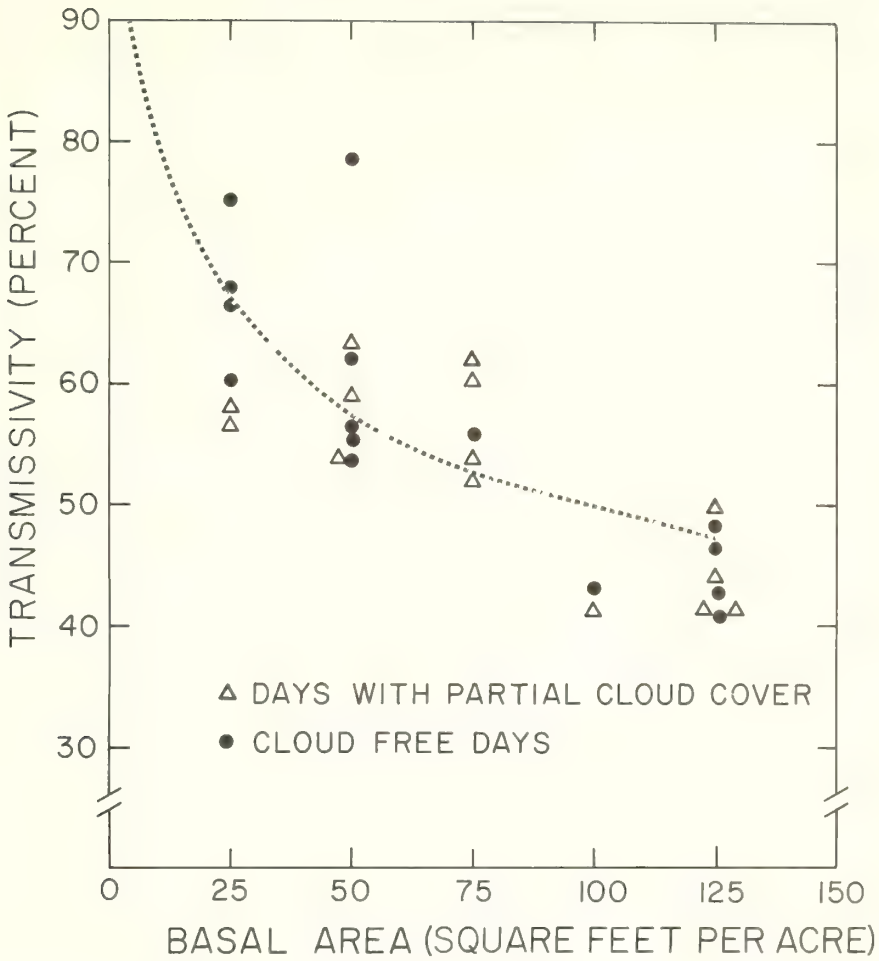


Figure 1.—Correlation of transmissivity against basal area at the five levels of basal area represented by the sample plots. The regression is obviously curvilinear because 100, 0 is a known point.

Results of this study suggest that correlation between transmissivity and basal area—an easily measured forest stand parameter—may be used to estimate the energy source for snowmelt prediction in Arizona's ponderosa pine forests.

Literature Cited

Muller, Robert A.
1971. Transmission components of solar radiation in pine stands in relation to climatic and stand variables. USDA For. Serv. Res. Pap. PSW-71, 13 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Reifsnyder, William E., and Howard W. Lull.
1965. Radiant energy in relation to forests. U.S. Dep. Agric., Tech. Bull. 1344, 111 p.

Thompson, J. R., and A. D. Ozment.
1972. The Rocky Mountain millivolt integrator for use with solar radiation sensors. USDA For. Serv. Res. Note RM-225, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Warskow, William L.
1971. Remote sensing as a watershed management tool on the Salt-Verde watershed. Appl. Remote Sensing of Earth Resour. in Ariz. (ARETS) Symp. [Tucson, Ariz., Nov. 1971] Proc. 2:100-108.

Agriculture—CSU, Fort Collins

g t 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM. 319

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT

Container-Grown Ponderosa Pine Seedlings Respond to Fertilization

David P. Trujillo[1]

Fertilizing containerized ponderosa pine seedlings with Hoagland nutrient solution did not stimulate seedling growth in the greenhouse. Fertilization was then terminated and seedlings were planted in pots. Growth during the subsequent 7 months was significantly stimulated by the pre-fertilization. Seedlings planted in punched holes in compacted soil grew better than those planted in loose soil.

Keywords: Containerized seedlings, fertilizer, bulk density.

Planting nursery stock has been the most successful method of regenerating ponderosa pine in most areas of the Southwest (Heidman 1963, Schubert et al. 1970). However, planting is becoming increasingly more expensive. Natural regeneration and direct seeding measures, although less costly, are applicable only in special situations. Planting container-grown trees is an attractive alternative to seeding and planting nursery stock.

This Note reports the effect of fertilization in the greenhouse on the subsequent growth of these seedlings planted in cans of soil by two methods.

Methods

Six-month-old ponderosa pine seedlings raised in containers were grown an additional 6 months in a greenhouse under four fertilization regimes. The growing units measured 20¼ by 13¾ by 4½ inches, and contained four compartments of 48 cells each, 1 inch in diameter and 4½ inches deep. Each cell contained one ponderosa pine seedling growing in peat moss.

The four compartments in each unit were each randomly assigned one of the following treatments: full-, half-, or quarter-strength Hoagland nutrient solution, or water.

Fresh nutrient solution was mixed in a 20-liter carboy once a week and applied to the seedlings with a siphon. In addition, the seedlings were watered with plain water approximately twice a week.

After 6 months the fertilization was stopped, and 10 seedlings from each treatment were used to determine the ovendry weights of tops and roots. At the same time, 200 seedlings, 50 from each treatment, were planted in pots containing a silty-clay loam soil collected from the Fort Valley Experimental Forest. The experimental design used was a split plot with five replications. Each replication consisted of five trees from each treatment planted to simulate the **dug-hole method** of planting, and five trees planted by a **punched-hole method** in compacted soil. Each replication therefore contained 40 seedlings.

Each pot was filled with 1,500 g of soil collected from the A and B soil horizons. For the dug-hole method of planting, the containerized seedling with its associated soil was held in place in the pot and the soil filled in around it. The soil in pots used for the punched-hole planting method was compacted as follows: each pot received 200 ml of water to bring it to approximate field capacity. After 2 hours the pots were tamped three times on a concrete floor. Each

[1]*Forestry Research Technician, located at the Forestry Sciences Laboratory at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

pot then received 50 ml of water every other day for the next 14 days. Pots were then allowed to dry for 10 days. One containerized seedling was planted in each pot in a hole created by pounding a steel dowel into the soil. The bulk density of the dug-hole method was 1.02; of the punched-hole method, 1.28.

Pots were arranged in blocks on the floor of the greenhouse and re-randomized weekly. Each pot received from 100 to 150 ml of plain water weekly from an automatic pipette. The temperature in the greenhouse ranged from 60° to 85°F.

The study was terminated in December after seedlings had grown in pots for 7 months. Top height and stem diameter of each seedling were determined, as well as the ovendry weight of the top and roots. The data were analyzed for significant differences by analysis of variance.

Table 1.--Growth of 1-year-old ponderosa pine seedlings as affected by Hoagland nutrient solution

Treatment number and solution strength	Mean ovendry weight[1]			Mean seedling height[2]
	Top	Root	Total	
	- - - *Grams* - - -			*Millimeters*
I--Full	0.3549	0.2796	0.6345	66
II--Half	.3892	.4159	.8051	70
III--Quarter	.3361	.4289	.7650	73
IV--Water only	.2516	.3009	.5525	64

[1]10 seedlings from each treatment.
[2]50 seedlings from each treatment.

Results

Trees fertilized with one-fourth strength Hoagland nutrient solution were darker green than trees fertilized with full- or half-strength solution (fig. 1). The latter two were yellowish, although the yellow disappeared 2 months after planting. Thus full- and half-strength solutions may have been toxic to the seedlings.

Ovendry weights (table 1) of the tops and roots after fertilization showed no significant differences among treatments. After growing in pots for 7 months, however, seedlings did show responses to the fertilizer treatments. Seedlings fertilized with Hoagland solutions were superior to seedlings receiving only water (table 2). For root weights (fig. 2), the differences among treatments were significant ($P<.01$). Fertilization significantly ($P<.01$) increased stem diameter compared to water only, but there were no significant differences among the three concentrations of nutrient solution. Top height growth was not significantly different among the three solution treatments.

Seedlings planted by the punched-hole method grew better than seedlings planted by the dug-hole method. For seedlings planted by the punched-hole method (1) top growth was significantly greater at $P=.10$, (2) root weights were significantly greater at $P<.01$, and (3) top weights were significantly greater at $P=.05$.

Figure 1.—One-year-old containerized ponderosa pine seedlings after 6 months of fertilization in the greenhouse. Note the vigor of the tops of the fertilized seedlings I, II, and III as compared to IV (which received only water).

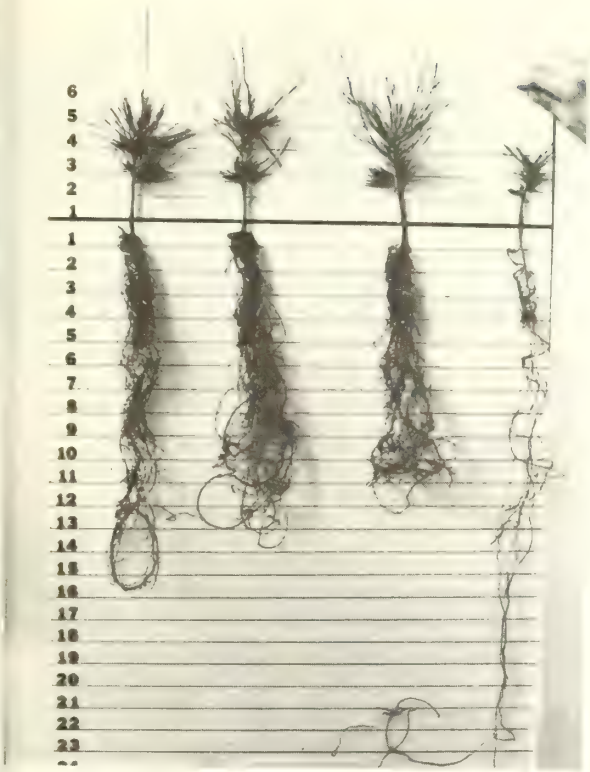


Figure 2.—Root growth of ponderosa pine seedlings (planted in loose soil) continued responding to fertilization while growing in pots for 7 months. Note vigor of tops and especially roots of the fertilized seedlings (left to right) I, II, and III as compared to IV (which received only water).

Table 2.--Effects of fertilizer treatments and planting methods on growth of ponderosa pine seedlings after 7 months in a greenhouse (mean of 25 seedlings)

Method, treatment number, and solution strength	Ovendry weight		Stem diameter	Top growth increment
	Top	Root		
	- - *Grams* - -		*Millimeters*	
DUG-HOLE:				
I--Full	1.26	1.78	3.9	13.0
II--Half	1.17	1.66	4.1	16.8
III--Quarter	1.51	2.14	3.9	16.1
IV--Water only	0.74	1.20	3.1	15.8
Total	4.68	6.78	15.0	61.7
PUNCHED-HOLE:				
I--Full	1.56	2.22	4.2	18.0
II--Half	1.48	2.35	4.0	16.2
III--Quarter	1.35	1.99	3.9	16.0
IV--Water only	1.01	1.49	3.5	16.0
Total	5.40	8.05	15.6	66.2

Summary and Conclusions

Three strengths of Hoagland nutrient solution did not stimulate seedling growth during 6 month's fertilization in the greenhouse, but seedlings receiving quarter-strength solution appeared to be healthiest.

During 7 month's growth after planting, however, seedling growth was stimulated by the pre-fertilization. All nutrient strengths were superior to water, but there were no significant differences among strengths. Therefore, quarter strength is most practical since it produced the best overall growth at least cost.

The punched-hole planting method resulted in superior tree growth, perhaps because of better soil water-root relations. The compacted soil quite possibly resulted in better capillary flow of water. The uncompacted soil most likely had more air-filled pores (Heidmann 1974).

Literature Cited

Heidmann, L. J.
1963. Effects of rock mulch and scalping on survival of planted ponderosa pine in the Southwest. U.S. For. Serv. Res. Note RM-10, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Heidmann, L. J.
1974. An investigation into the causes and prevention of frost heaving of forest tree seedlings. Ph.D. Diss., Univ. of Ariz., 183 p. Tucson.

Schubert, G. H., L. J. Heidmann, and M. M. Larson.
1970. Artificial reforestation practices for the Southwest. U.S. Dep. Agric., Agric. Handb. 370, 25 p.

gst 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-320

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Chemical Properties of Chaparral Fuels Change During Preheating Before Flaming

David P. Trujillo[1]

Two chaparral species, pointleaf manzanita (*Arctostaphylos pungens* H.B.K.) and shrub live oak (*Quercus turbinella* Greene), were analyzed for certain chemical properties known to influence flammability. Half of each sample was analyzed before heating, and the other half after heating for 5 minutes. The losses of crude fat, heat of combustion, and phosphate-phosphorus were statistically significant.

Keywords: *Arctostaphylos pungens*, *Quercus turbinella*, flammability.

Fuel chemistry and fuel physics have a pronounced influence on fire behavior. Lindenmuth and Davis (1973) found that the phosphate-phosphorus content of fuels affects rate of spread (ROS) appreciably. They concluded that "there is a critical threshold at 0.235 percent; with decreasing PO_4 below that level ROS increases, with increased PO_4 above the threshold there is no change in ROS." Crude fat (oils and waxes), water, and phosphate-phosphorus directly influence fuel flammability and total energy yield of forest fuels. Therefore, changes in these constituents during preheating before flaming may affect the flammability of fuels.

This Note reports changes, during the preheating period, in the crude fat, phosphate-phosphorus, and heat of combustion of leaves of two primary chaparral species.

Procedure

Fully developed, live manzanita and shrub live oak leaves were collected in August (summer), October (fall), and February (winter). After the leaves were freeze-dried for 48 hours, half of each sample was set aside as a matching control (Davis 1968). The remaining half was heated with an infrared lamp. The manzanita leaves were exposed to 428°F for 5 minutes, and the oak leaves 382°F for an equal period of time. The purpose of preheating was to simulate the effects of an approaching fire on chemical properties of the fuel before ignition. The weight loss and temperature obtained were recorded for each prepared sample. The control samples and the heated samples were then ground in a Wiley laboratory mill to pass a 40-mesh screen.

Crude fat content was measured by extracting two 1-gram subsamples with anhydrous ether for 4 hours in a Goldfish fat extraction apparatus. Samples were then ovendried at 70°C for 24 hours, by which time a constant weight was reached.

Heat of combustion (total energy a fuel has available for release in burning) was determined in a Parr isothermal oxygen bomb calorimeter (Parr procedure).

Phosphate-phosphorus concentrations were calculated in parts per million by weight (Johnson and Ulrich 1959). Samples were treated to develop the blue phosphomolybdate color, which was then measured on a photoelectric colorimeter.

Moisture content for the above samples was determined by the Karl Fischer titration method to establish the dry-weight bases for chemical comparisons. Moisture losses due to preheating have no real meaning in this study because the leaves had been freeze dried.

[1]*Forestry Research Technician, located at the Forestry Sciences Laboratory at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Table 1.--Effects of preheating on chemical content of chaparral fuels collected during different seasons (mean of 10 replications)

Species and season	Crude fat			Phosphate-phosphorus			Total energy			Weight loss		
	Before	After	Difference	Before	After	Difference	Before	After	Difference	Before	After	Difference
	- - *Percent* - -			*p.p.m.*		*Percent*	*cal/g*		*Percent*	- *g* -		*Percent*
MANZANITA:												
Summer	8.0	6.6	17.5	2,549	1,711	32.9	5,122	4,763	7.0	5.27	4.69	11.0
Fall	9.6	7.7	19.8	2,538	1,217	52.0	5.264	4,815	8.5	10.04	8.90	11.3
Winter	9.3	7.7	17.2	2,316	1,666	28.1	5,377	4,731	12.0	10.11	8.82	12.7
OAK:												
Summer	2.6	2.3	11.5	3,261	2,593	20.5	4,675	4,545	2.8	5.08	4.79	5.8
Fall	4.2	4.1	2.4	3,367	1,802	46.5	4,738	4,561	3.7	5.01	4.68	6.5
Winter	5.6	4.6	17.9	2,227	2,414	8.4	4,844	4,510	6.9	10.03	9.28	7.5

Results and Discussion

Dry chaparral leaves lost approximately 14 percent of their weight during the preheating period. The weight loss was indicated by gas vapors and smoke.

All the preheated leaves lost statistically significant amounts of water, crude fat, total energy, and phosphate-phosphorus (table 1).

Crude fat loss is also important because crude fat may contain 9,300 calories per gram, over twice the average 4,100 calories for all other fuel components combined (Crampton 1956). Davis (1968) found crude fat in manzanita to yield 9,212 calories per gram, while oak fat yielded 8,474 calories per gram. The crude fat losses did not account for the differences in total energy between the controls and the preheated samples, however.

Conclusions and Recommendations

Chemical changes brought about by preheating reduce crude fat, moisture content, phosphate-phosphorus content, and total energy yield of chaparral fuels. The total effect of these changes would appear to increase the flammability of the fuel, in spite of the fact that some of the chemical responses appear to be offsetting. For example, preheating tends to reduce the moisture content of the fuel, thereby **increasing** flammability. However, preheating also reduces the amount of crude fat slightly, which should **reduce** flammability. Preheating reduces the amount of phosphate-phosphorus, which should result in an **increase** in flammability. However, preheating also reduces the total energy yield of the fuel, which should make the fire **less** intense. The fact that the total of the measured losses did not account for the total weight loss caused by heating suggests that other constituents are being driven off. When these changes are based on a larger scale, such as a 20-acre fire, the effects on flammability may influence the characteristics of the fire itself.

Literature Cited

Crampton, E. W.
1956. Applied animal nutrition. 458 p. W. H. Freeman & Co., San Francisco.

Davis, James R.
1968. Freeze drying for preparing Arizona chaparral plants for energy analysis. USDA For. Serv. Res. Note RM-106, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Johnson, C. M., and A. Ulrich.
1959. Analytical methods. Calif. Agric. Exp. Stn. Bull. 766, 7 p.

Lindenmuth, A. W., Jr., and James R. Davis.
1973. Predicting fire spread in Arizona's oak chaparral. USDA For. Serv. Res. Pap. RM-101, 11 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Agriculture—CSU, Fort Collins

1976

U S D A FOREST SERVICE
RESEARCH NOTE RM 321

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

Laboratory Evaluation of Wax and Silicone for Water Harvesting on Coal Mine Spoil

David G. Scholl [1]

New Mexico coal mine spoil treated with either silicone or wax developed water-repellent crusts; the wax crust withstood disturbance better and retained more repellency. Increasing the application rate generally improved performance of both crusts. Both treatments appear suitable for harvesting water to aid plant establishment on coal mine spoil.

Keywords: Revegetation, reclamation.

Currently in the Southwest, water harvesting is used to augment water supplies for livestock or wildlife. The practice generally consists of treating or covering the soil surface on a small watershed (less than 1 ha) to increase and collect runoff. A variety of materials have been used: salt, plastic sheet, and sprayed asphalt (Aldon and Springfield 1975, Myers 1967, Rauzi et al. 1973), butyl-sheet and wax (Aldon and Springfield 1975, Fink et al. 1973), and water-repellent chemical sprays (Myers 1967). The treatments vary, both in harvesting efficiency and cost of installation, from the inexpensive salt treatment with low efficiency, to high-cost butyl rubber with high efficiency. Other factors such as treatment longevity, resistance to erosion, and water quality, also vary.

Selection of the wax and silicone materials in the present study was based mainly on cost and ease of application. The objective of this study was to evaluate, by laboratory methods, their use in waterproofing coal mine spoil, and to determine minimum rates of application for plant establishment work.

In scope, the study will explore in some detail the relationships between concentration and application rate of silicone since little is known about the material. Because the wax is applied as a granular product, comparisons between materials for the above parameters cannot be made.

Methods

The two materials were applied at various rates to spoil collected at the McKinley Mine near Gallup, New Mexico. The spoil material is a moderately saline (EC = 5 mmhos/cm, SAR = 10), mildly alkaline (pH = 7-8) clay with poor aggregation. The spoil is derived mainly from poorly consolidated gray shale, and contains 10-25 percent shale fragments (0.2-1 cm). A composite of several subsamples of recently mined material was passed over a 1-cm screen to eliminate any large fragments. The spoil material was placed in wooden nursery flats (17 x 19 cm), and compacted dry to a 5-cm depth. Each flat had either a wax or silicone treatment at one of several rates of application. The flats were arranged in a random manner with control flats interspersed. All treatments were replicated three times, and the results used in a regression analysis.

The containers, after treatment, were placed in full summer sun (36°C daily maximum air temperature) for 5 days. This conditioning was necessary to cure the latex binder in the silicone treatment, and completely melt the wax.

[1] *Soil Scientist, located at the Station's Research Work Unit at Albuquerque in cooperation with the University of New Mexico; Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Silicone-Latex Treatment

Four different concentrations (3, 6, 9, and 12 percent suspended solids in water) of a 3 to 1 mixture of SBR latex and silicone emulsion (Dow Corning xz8-5079) were sprayed on the spoil. The rate of application was maintained at 3 l/m^2 using a hand spray bottle. Four rates of application (1.5, 3.0, 4.5, 6.0 l/m^2) were also tested at a constant 6 percent concentration. The control flats were sprayed with distilled water at the above rates of application.

Wax Treatment

Four rates (0.25, 0.5, 1, 1.5 kg/m^2) of ground paraffin were hand scattered over the spoil samples. Five-pound slabs of paraffin (55°C melting point) were frozen, broken into pieces, and passed through a garden shredder to produce the granules (0.1-10 mm used).

Penetration Test

Penetration of the crust formed in the containers was measured by counting the number of blows from a 500 g weight (2-cm vertical travel) required to drive a steel rod (4 mm diameter) through the crust. The above method was used, rather than a conventional penetrometer, because it was better adapted to the special conditions in the flats. Ten such tests were performed at equal spaces in the containers. Results of the 10 tests were averaged within each container.

Water Stability and Crust Thickness

A 2 cm^2 piece of the crust was placed in a 50 ml stoppered vial (half filled with water) and shaken by hand until 50 percent of the crust was broken down. The number of strokes (30 cm horizontal travel) required for the breakdown was recorded for five pieces, and the results averaged within each container. This method was chosen as a simple way to evaluate the relative stability of the crusts. The average thickness (cm) of each crust piece was also recorded and averaged within containers.

Water Repellence

The treated surface was tested for water repellence by the drop disappearance method. The procedure consists of placing drops of water of uniform size (using an eye dropper) on the spoil surface and timing their disappearance.

Results

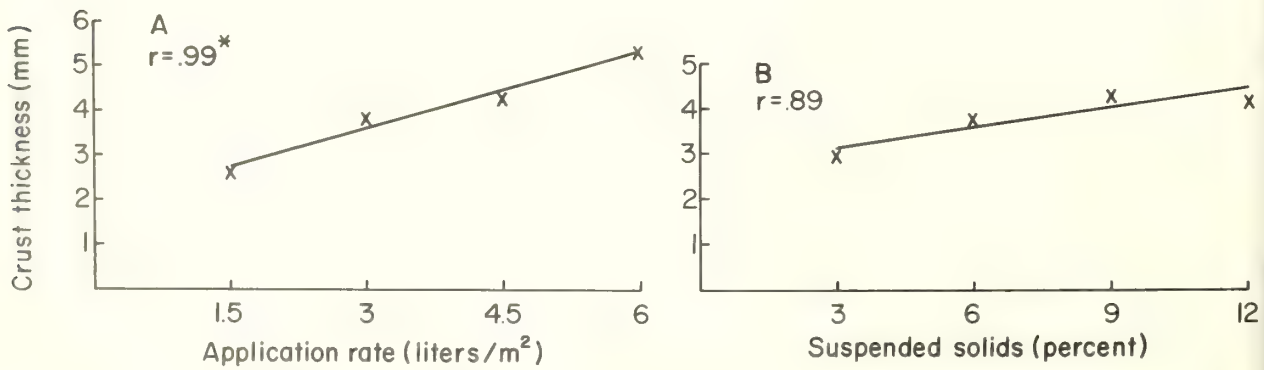
Silicone-Latex Crust

All of the silicone-latex treatments produced crusts that were significantly stronger and more water stable than the control crusts. The control crusts were also generally thinner and showed little water repellence.

Thickness.—Crust thickness was influenced mainly by the amount of fluid applied (fig. 1A). Increasing the amount of fluid undoubtedly increased the depth of penetration. As drying began, the latex binder apparently remained in place and formed crusts with thickness in proportion to fluid penetration.

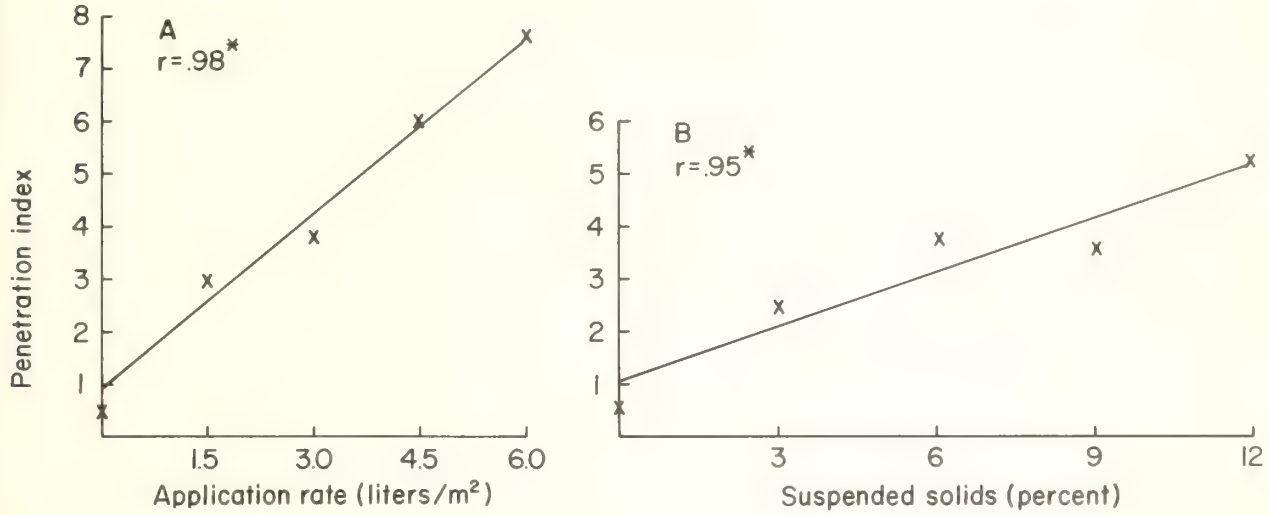
Crust thickness, however, was not greatly influenced by the concentration of the fluid at the 3 l/m^2 rate (fig. 1B), although a positive trend is shown. Depth of fluid penetration apparently is not greatly affected by concentration, at least in the range less than 12 percent.

Figure 1.—**A**, The influence of volume applied (6 percent suspended solids) of silicone-latex on crust thickness. **B**, The influence of concentration (application rate = 3 l/m^2) of silicone-latex on crust thickness.



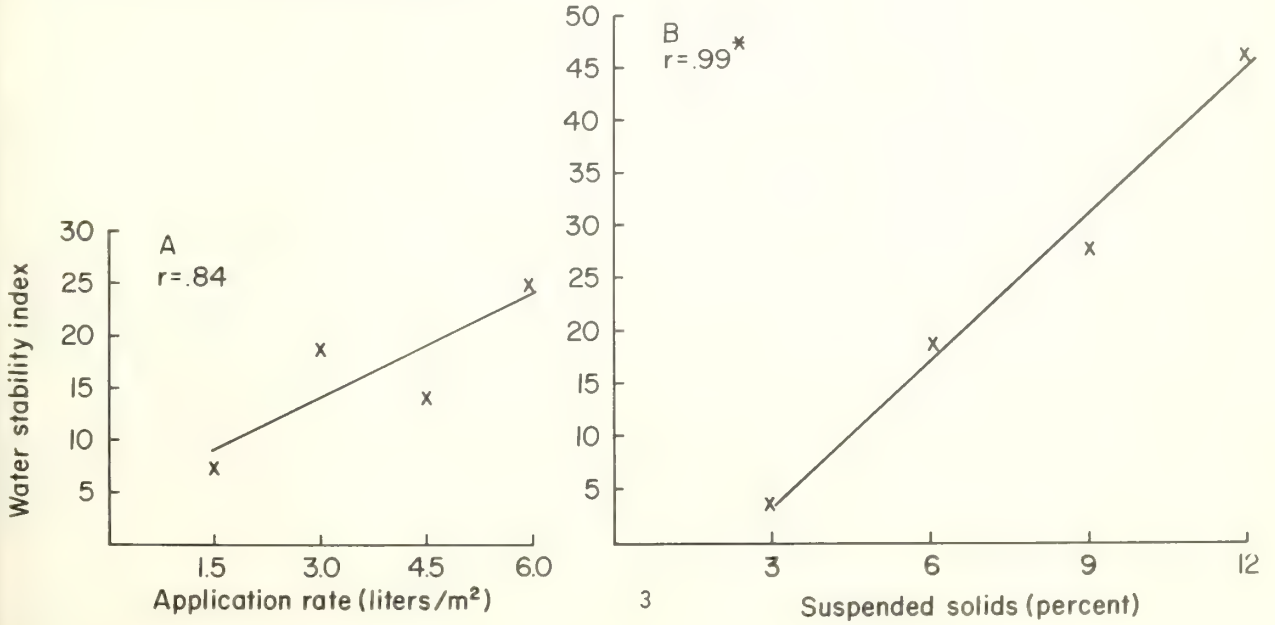
Penetration.—Both the concentration of the fluid and the rate of application affect resistance to penetration (fig. 2A, 2B). An increase in latex concentration increases crust strength at a given thickness (fig. 2B). A thicker crust, a result of high application rates, also improves resistance to penetration (fig. 2A).

Figure 2.—**A,** The influence of volume applied (6 percent suspended solids) of silicone-latex on penetration. Penetration index is the number of blows from the 500 g weight.
B, The influence of concentration (application rate = 3 l/m²) of silicone-latex on penetration.



Water Stability.—Water stability of the crust is influenced mainly by the concentration of the fluid, although increasing the rate of application does show a trend toward higher stability (fig. 3A, 3B). Increasing the fluid concentration improves water stability, while higher rates of application may not. The higher rates increase crust thickness and strength, but may not improve its water stability.

Figure 3.—**A,** The influence of volume applied (6 percent suspended solids) of silicone-latex on water stability. Water stability index is the number of times a vial, containing water and a piece of the crust, is shaken to produce appreciable crust breakdown.
B, The influence of concentration (application rate = 3 l/m²) of silicone-latex on water stability.



Water Repellence.—There were no significant differences in water repellency of undisturbed crusts at the different rates of application (47-55 minutes for drop disappearance). All concentration levels greater than 3 percent were grouped together at 55-60 minutes. The 3-percent level was significantly lower (7 minutes).

If the crusts were fractured with a sharp instrument, however, water repellency changed drastically. Drops placed over a fracture (2 mm wide) were immediately absorbed. In cross section, the fractured crusts showed water repellence only on the upper portion (1-2 mm). The loss of repellency with fracturing was most pronounced at the lower concentration and application rates.

Wax Crusts

Wax did not form a continuous rigid crust at any of the rates used. At all application rates, however, wax-treated spoil became completely water repellent (water drops disappeared only by evaporation). Considerable mixing with untreated material was needed to produce water absorption.

Comparisons of thickness, stability, and penetration of the wax "crusts" with those of the silicone were not made. Obviously, these factors were not as well correlated with water repellence in the wax case as in the silicone. There were, however, some obvious changes in the wax "crust" with increasing rate of application. The lowest rate (0.25 kg/m^2) produced only occasional soft lumps in the treated layer, while the highest rate (1.5 kg/m^2) produced an almost continuous soft crust. With the granule size used, the two lower rates did not completely treat the surface. Untreated spots occurred around some of the larger granules. Better surface coverage would have been possible with finer material. Wax penetration in the spoil varied from 0.8 cm (lowest rate) to 2 cm (highest rate).

Conclusions and Recommendations

Silicone-Latex

Both strength and water repellence of crusts are influenced by concentration and rate of application; increasing either improved the performance of the crust. Concentrations lower than 6 percent suspended solids sprayed at 3 l/m^2 are not recommended. Lower concentrations will likely produce poor water repellence and thin, fragile crusts. Since both cost and service life increase with higher rates and concentrations, specific requirements must be considered. Where water harvesting is needed only for a short time (plant establishment), a minimum rate of 6 percent solids sprayed at 3 l/m^2 should suffice.

Service life at the above rate may be restricted, however, to only the first growing season. This conclusion comes from a related study at the mine site where the above treatment (under field conditions) failed completely after 1 year.

Wax

Strength and water repellence were not greatly affected by various application rates of wax. Water repellence was significantly better at all rates than any of the silicone-latex treatments. Although the wax crusts lacked strength compared to silicone-latex, they retained their water repellence under mechanical disturbance.

Rates lower than 0.5 kg/m^2 are not recommended because of poor surface cover and shallow penetration. Surface cover could be improved at these rates with finer grinding and careful distribution. The 0.5 kg/m^2 rate should be quite acceptable for plant establishment work during the first growing season.

In the companion study at the mine site, the wax treatment (0.5 kg/m^2) had 20 percent of the original surface intact after 1 year of field exposure.

Literature Cited

Aldon, Earl F., and H. W. Springfield.
1975. Using paraffin and polyethylene to harvest water for growing shrubs. Proc. Water Harvesting Symp., Phoenix, Ariz., March 26-28, 1974. ARS W-22, p. 251-257.

Myers, Lloyd E.
1967. Recent advances in water harvesting. J. Soil and Water Conserv. 22(3):95-97.

Fink, D. H., K. R. Cooley, and G. W. Frasier.
1973. Wax treated soils for harvesting water. J. Range Manage. 26:396-398.

Rauzi, Frank, Merle L. Fairbourn, and Leland Landers.
1973. Water harvesting efficiencies of four soil surface treatments. J. Range Manage. 26:399-403.

The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.

Use of trade or company names is for the benefit of the reader, and does not constitute endorsement by the U.S. Department of Agriculture.

st 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-322

OREST SERVICE
S DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Snow Damage in Arizona Ponderosa Pine Stands

Peter F. Ffolliott[1] and J. R. Thompson[2]

Snow damage in three cutover ponderosa pine stands was evaluated following a year of record snowfall in north-central Arizona. Susceptibility to bending decreased as d.b.h. increased. Dense sapling stands suffered significantly more damage than thinned areas. Thinning early in the sapling stage is recommended to reduce the snow damage potential.

Keywords: *Pinus ponderosa*, snow damage.

Dense conifer stands in sapling and pole sizes are frequently damaged by heavy snow (Fenton 1959, Kangur 1973, Powers and Oliver 1970, Watt 1951). However, little information is available to characterize snow damage in ponderosa pine (*Pinus ponderosa* Laws.) stands in Arizona. Pearson (1950) reported pole-sized trees may be seriously damaged by snow, and Schubert (1971) found 12 percent of the trees in the Taylor Woods thinning study, mostly saplings, were bent or broken after a spring of wet snow.

In the study reported here, snow damage in three cutover ponderosa pine stands was evaluated following a year of record snowfall in north-central Arizona. Snow damage and subsequent recovery are related to tree size and stand density.

Methods

The three study areas were located: (1) 8 miles south of Flagstaff, on the Coconino National Forest; (2) 6 miles east of McNary, on the Fort Apache Indian Reservation; and (3) 7 miles south of Alpine, on the Apache-Sitgreaves National Forest. Uneven-aged stands of cutover ponderosa pine, with different age classes occurring as even-aged groups, characterize the areas. Some areas had been thinned at least 10 years previously. Site index values range from 50 to 75 feet at 100 years (Minor 1964). Elevations extend from 7,400 to 8,000 feet, and soils on all areas are developed from basalt and volcanic cinders.

One-fifth-acre plots were permanently established on the study areas, 30 each at Flagstaff and McNary, and 40 plots at Alpine. Trees on each plot were tallied by diameter at breast height (d.b.h.) as part of other investigations. After the record snowfall in 1972-73 (Barnes et al. 1974), these tallies provided the base from which snow damage was evaluated. Following this season of record snowfall, trees were classified as bent, broken, or not damaged. Damaged trees were reexamined annually for 3 years to determine recovery.

Results and Discussion

No differences were found in the size of trees or density of stands damaged by snow among the three study areas. Therefore, the data were grouped for further analysis.

While a few broken tops were observed, most of the damage resulting from the 1972-73 snowfall involved bent stems. Bending varied from slight deviations in straightness to situations where bowed stems almost touched the ground (fig. 1). Subsequent recovery of bent stems has been slow; over 95 percent of the trees initially damaged are still bent to some degree 3 years later. No mortality attributable to snow damage was recorded.

[1]*Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona.*

[2]*Principal Meteorologist, Forest Hydrology Laboratory, Rocky Mountain Forest and Range Experiment Station, Tempe, in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Figure 1.—Snow damage on the White Mountain sample plots consisted mainly of bending. Bending varied from a slight lean to situations where the crowns touched the ground.

Susceptibility to bending by snow decreased as d.b.h. increased. Most of the bending was confined to saplings (2-inch d.b.h.), with no damage in trees over 6 inches d.b.h.:

D.b.h. (Inches)	Total trees (No./acre)	Bent stems (No./acre)
2	158.8	30.6
4	120.7	4.58
6	90.6	0.37
8	58.7	0

Although we found no relationship between snow bending and total stand basal area, dense sapling stands suffered significantly more damage than thinned areas. The dense, meshlike canopy structure of these stands intercepted and accumulated heavier snow loads than isolated tree crowns. Also, when these sapling stands occur as an understory, the snow loads released from the overstory crowns can increase the bending damage (fig. 2).

We found no relationship between the little stem breakage that was observed and tree size or stand density; similarly, there was no correlation between height to break and total height.

The potential damage arising from excessive snow loads might be reduced in Arizona ponderosa pine by thinning early in the sapling stage. Apparently, trees grown in open stands in seedling and sapling stages are better able to resist snow damage (Kangur 1973).

Figure 2.—Dense stands had more snow damage than thinned stands, and the smaller trees were hardest hit.

Literature Cited

Barnes, James C., Clinton J. Bowley, and David A. Simmes.
1974. The application of ERTS imagery to mapping snow cover in western United States. ERTS Type III Final Report, NASA-LR-137223, Natl. Tech. Inf. Serv. E74-10400, 80 p.

Fenton, R. H.
1959. Heavy snowfalls damage Virginia pine. U.S. Dep. Agric., For. Serv., Northeast For. Exp. Stn., Res. Note 92, 4 p. Upper Darby, Pa.

Kangur, Rodolf.
1973. Snow damage to young western hemlock and Douglas-fir. Oreg. State Univ., For. Res. Lab., Res. Pap. 21, 11 p.

Minor, Charles O.
1964. Site-index curves for young-growth ponderosa pine in northern Arizona. USDA For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pearson, G. A.
1950. Management of ponderosa pine in the Southwest. U.S. Dep. Agric., Agric. Monogr. 6, 218 p.

Powers, Robert F., and William W. Oliver.
1970. Snow breakage in a pole-sized ponderosa pine plantation . . . more damage at high stand-densities. USDA For. Serv. Res. Note PSW-218, 3 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Schubert, Gilbert H.
1971. Growth response of even-aged ponderosa pine stands related to stand density level. J. For. 69:857-860.

Watt, R. F.
1951. Snow damage in a pole stand of western white pine. U.S. Dep. Agric., For. Serv., North. Rocky Mt. For. and Range Exp. Stn., Res. Note 2, 4 p. Missoula, Mont.

Agriculture—CSU, Fort Collins

S.79:RM-323

ember 1976

USDA FOREST SERVICE
RESEARCH NOTE RM-323

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Some Reflections on Biological Studies of Needle Diseases[1]

Glenn W. Peterson[2]

Biological investigations of several needle diseases are being conducted in widely separated locations. To increase our understanding of the biology of such diseases, results from research conducted in these different locations need to be compared and differences resolved. Presented herein are examples of differences and ways of resolving them with minimal effort, for example, using comparable experimental methods. Comments on the confusion resulting from use of ambiguous terms in specifying needle age are included, and suggestions are offered for clarification.

Keywords: Needle diseases (conifers), tree diseases, pathogen, germination, germ tube.

There has been a rapid increase in the number of investigations of the biology of needle diseases during the last 15 years. These investigations are providing basic information needed for prevention or control of needle diseases by use of genetic resistance or by direct means (fungicides). In many instances, the same diseases are being studied in widely separated locations, particularly those diseases which are economically important. For a more complete understanding of the biology of such diseases, the results from investigations conducted in widely separated locations need to be compared and differences resolved.

There are several obstacles to making needed comparisons, such as differences in the (1) pathogen (strain or species), (2) hosts, and (3) environment. Many differences could be resolved if pathogens from several locations could be used at one or more locations for cross-inoculation studies. Movement of viable fungi for taxonomic studies involving only laboratory work involves low risk of introducing "new" strains to hosts in a given area; however, movement for cross-inoculation purposes has high risk and should be attempted only under certain special conditions.

There is less of a problem in investigating in one location the reaction of hosts from several locations, since hosts can be established in new locations from seed with low risk of introducing pathogens. Actually, the environment may not favor the development of introduced hosts; and even if the new hosts were to develop, the interactions of host and pathogen with environmental factors may result in reactions far different than in locations where the pathogen and hosts are indigenous.

In spite of these serious obstacles, there is considerable comparative work that can be done which will

[1] *Paper presented at XVI IUFRO Congr., Oslo, Norway, June 1976.*

[2] *Plant Pathologist, located at the Station's Forestry Sciences Laboratory, Lincoln, in cooperation with the University of Nebraska; station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

increase our knowledge of the biology of needle diseases. For instance, we can evaluate the work of our colleagues and repeat their critical experiments in our locations. Sometimes this can be done with minimum effort. I would like to present some examples.

I reported several years ago that tubes of *Dothistroma pini* conidia were positively directed toward stomata on needles of Austrian and ponderosa pines in eastern Nebraska, U.S.A. (Peterson 1969). Some pathologists investigating infection of Monterey pine by *D. pini* reported that germ tubes were not positively directed toward stomata (Gadgil 1967, Ivory 1972). My information was obtained by observing plastic prints of the surfaces of needles collected in the field. In contrast, observations of germination on Monterey pine needles had been made on needles of seedlings that had been artificially inoculated and then incubated under high humidity. I have found that under such conditions germ tubes of *D. pini* are not positively directed toward stomata on needles of Austrian and ponderosa pines (unpublished data). Possibly, this directed growth of germ tubes is related to a water gradient from stomata to germ tubes and that incubation under high moisture destroys the gradient.

In a recent publication (Setliff and Patton 1974), it was reported that germ tubes of *Scirrhia acicola* conidia were not positively directed toward stomata on Scots pine needles. The authors had observed germination on needles artificially inoculated and incubated under high moisture. In contrast, I have made plastic prints of needles from Scots pine located in a plantation and observed that a high percent of germ tubes were positively directed toward stomata.

We must use artificial conditions in our investigations, but we should try to determine if the phenomena observed under such conditions are comparable to phenomena under natural conditions. Often the differences can be resolved with minimum effort, as is the case in the examples given above.

Spore germination experiments are routinely conducted by most laboratories to determine the effect of temperature on germination. Two of the most commonly used methods involve germination in water (Van Tieghem cells) or germination on solid media such as water agar. Investigators seldom conduct tests using both liquid (water) and solid media. Thus, in comparing germination results, it frequently is not possible to determine whether apparent differences in results are related to methods or to different "strains" of the fungus. Again, this problem can be resolved with minimum effort.

Most reports on spore germination do not include data on germ tube growth, but such data would increase considerably our knowledge of pathogens. For example, percent germination for many pathogens is near optimum over a relatively wide temperature range, but germ tube growth is usually near optimum over a much narrower temperature range.

The standardization of methods for producing spores for inoculations is essential when a series of experiments is to be conducted. Thus when the cultures from which spores are obtained for a series of experiments include a broad range of ages (3 to 6 weeks, for example), care must be taken to see that culture age does not have a significant influence on germination. Even slight differences in culture age may cause large differences in germination. In work with *Cercospora sequoiae* var. *juniperi* on *Juniperus* species, we found striking differences in percent germination and germ tube lengths of spores from 7- to 14-day-old (carrot-leaf decoction agar) cultures.[3] After incubation on water agar for 24 hours at 24°C percent germination and germ tube lengths for spores from 7-day-old cultures were 91 percent and 48 micrometers, for 10-day-old cultures 57 percent and 22 micrometers, and for 14-day-old cultures 10 percent and 10 micrometers.

Needle age is not adequately specified by some investigators of needle diseases. Those concerned with the biology of needle diseases usually include information on needle age in their reports; however the terminology is often confusing. Terms such as **one-year-old, two-year-old** are frequently used in the literature from English-speaking countries. In most papers when one-year-old is used, needles of the second year are being referred to; but in others reference is actually being made to **current-year** needles. I do not recommend standardization of terms for use in specifying needle age, since no system of terms would be adequate for all situations. I suggest the discontinuance of the use of one-year-old and two-year-old when referring to age of needles on trees in stands. I recommend the use of **first-year** and **second-year** in specifying needle age, but it must be indicated that **first-year** refers to **current-year.**

Mycologists studying needle-inhabiting fungi can apparently achieve their taxonomic objectives without reference to needle age, since seldom do their publications include information on age of needles. In his first major treatment of the Hypodermataceae Darker (1932) included some information on needle age; but in later treatments he did not. I suggest that, when practical, those working on taxonomic aspects (mycologists, pathologists) include in their publications information on needle age, even if the information is limited.

[3] *Peterson, Glenn W. Epidemiology and control of blight of* Juniperus virginiana *caused by* Cercospora sequoiae *var.* juniperi. (*Manuscript accepted for Phytopathology.*)

Pathologists working on the biology of needle diseases could in a similar way be more helpful to taxonomists if they would include in their publications information needed by taxonomists, such as dimensions and other characteristics of spores and fruiting bodies.

The incubation period (time between infection and first appearance of symptoms) is rather long for many needle diseases. This presents particularly difficult problems in determining when initial infection occurs. Information on when spores are first produced and dispersed may provide leads; however, there can be lengthy intervals between spore production and spore dispersal, and between spore dispersal and initial infection. Thus this type of information cannot provide conclusive information on time of initial infection.

If symptoms and fruiting bodies develop early in the growing season on current-year needles, rather accurate estimates can be made of the time of initial infection. Thus the determination of conditions under which infection can occur is simplified. If current-year needles are initially resistant to infection, as with *Dothistroma pini* on Austrian and ponderosa pine in eastern Nebraska, then indirect means will usually be needed to determine time of initial infection. In this case, time of initial infection was determined by leaving needles unprotected (not sprayed with fungicide) for specific periods of time, then protecting them with fungicide (Peterson 1965). Such tests are simple because several treatments can be made on a single tree, since only a few shoots need to receive the same treatment. In this manner information on variation in resistance among trees can be accumulated rapidly and with precision. Others have approached this problem by placing seedlings within infected stands for specific time periods, then removing them and observing for evidence of infection. This method can be effective, but caution should be exercised to assure that differences in susceptibility between seedlings and the trees in the stands do not confound results.

Incubation periods determined by artificial inoculation of seedlings may be useful for field determinations of initial infection. However, the incubation periods determined by artificial methods are usually much shorter than those in the field. For example, Gadgil (1974) in a fine series of experiments on *Dothistroma pini* infection of inoculated Monterey pine seedlings, obtained incubation periods of less than 2 weeks; however, in the field in New Zealand the incubation period on Monterey pine varies from 5 to 16 weeks (Gilmour 1967).

Determining when infection occurs throughout the growing season is more difficult than determining when initial infection occurs. Some investigators have approached this problem by placing bags over shoots prior to spore dispersal, removing the bags for a short period to expose needles to spores, and then replacing bags (or protecting shoots with fungicide). We have not been able to use this method because high temperatures within the bags had an adverse effect on shoots and needles. Furthermore, we found that when the shoots of ponderosa and Austrian pines were bagged, infection of the current-year needles occurred earlier than usual. We thought that this early breakdown in resistance of current-year needles might be due to the effect bagging had on needle surface waxes. To explore this possibility, we washed needles with wax solvents; however, the washed needles retained their resistance. We next sought to determine if the amount of surface wax on current-year needles in mid-July (when the needles became susceptible) differed from amounts present on needles earlier in the growing season (when needles were resistant). We did not find any differences in wax amounts that were correlated with time of change of needles from resistant to susceptible.[4] The methods of Schütt (1971) and Schuck (1972) should be used to determine if there are changes in the nature of the waxes during the growing season that might be correlated with change in resistance.

Those working on needle diseases are well aware that the amount of infection in one year may not provide information on the amount of infection the next year. Our first work on Dothistroma blight in eastern Nebraska included the installation of a control test. The year prior to the test, infection had been at a very high level in the plantation; but in 1959 there was essentially no infection; thus no information on control was obtained. During this test, I obtained data from a U.S. Weather Bureau station located 8 kilometers from the test site. A check of the weather records did not reveal an obvious reason for the lack of infection. Nor was information on the number of spores being dispersed sufficient to explain the lack of infection. It was at this point that I decided in subsequent work to periodically make plastic leaf prints of needles to determine what was happening to the spores on the needle surfaces. Through this means we were able to determine those periods in which high numbers of spores were dispersed but in which spores did not germinate on needles (Peterson 1973).

Usually several years' observations are needed to get a clear picture of fungus and disease development in the field (Lanier and Sylvestre 1971, Peterson 1973). The incubation period of *Dothistroma pini* is much shorter in western Oregon, than in the central

[4] *Walla, James A., and Glenn W. Peterson.* Dothistroma pini *and* Diplodia pinea *not affected by surface wax of pine needles.* (*Manuscript accepted for Plant Dis. Rep.*)

United States.[5] Though fruiting bodies may form on needles during the year of infection in eastern Nebraska, we rarely find conidia in these fruiting bodies until the following spring (April, May). In contrast, in Oregon conidia are frequently produced on needles infected during the current year. Are these differences due to "strains" of the fungus, different weather conditions, or both? There are differences in morphology between conidia from the central United States and the western United States (Funk and Parker 1966, Thyr and Shaw 1964). Certainly the weather is different. We have some suggestive evidence obtained from work in both areas.[5] In the central United States, the presence of conidia in the year of infection has occurred only during years when weather late in the growing season was unusually warm, but during which there were a few nights when temperatures were unusually low. Is the short incubation period in the West due to the lower nighttime temperatures which occur frequently there? We have a suggestion that this is the case, but are not certain.

Again this brings us back to the point made earlier, that for more rapid progress in the investigations of the biology of needle disease, we should resolve the differences in results obtained from different locations. Furthermore, we should examine some of the newer methods being used by some investigators and, where possible, use these methods in our locations. By so doing, we can more quickly explain phenomena associated with needle diseases and more quickly formulate principles that can be utilized in preventing or controlling needle diseases.

[5]*Peterson, Glenn W., and George M. Harvey. Dispersal of* Scirrhia (Dothistroma) pini *conidia and disease development in a shore pine plantation in western Oregon. (Manuscript accepted for Plant Dis. Rep.)*

Literature Cited

Darker, G. D.
1932. The Hypodermataceae of conifers. Contrib. Arnold Arbor. Harv. Univ. 1:1-131.

Funk, A., and A. K. Parker.
1966. *Scirrhia pini* n. sp., the perfect state of *Dothistroma pini* Hulbary. Can.J. Bot. 44:1171-1176.

Gadgil, P. D.
1967. Infection of *Pinus radiata* needles by *Dothistroma.* N. Z. J. Bot. 5:498-503.

Gadgil, P. D.
1974. Effect of temperature and leaf wetness period on infection of *Pinus radiata* by *Dothistroma pini.* N. Z. J. For. Sci. 4:495-501.

Gilmour, J. W.
1967. Distribution, impact and control of *Dothistroma pini* in New Zealand. XIV Int. Union For. Res. Org. Congr. [Munich, Sept. 1967] Proc., vol. 5, p. 269-278.

Ivory, M. H.
1972. Infection of *Pinus radiata* foliage by *Scirrhia pini.* Trans. Br. Mycol. Soc. 59:365-375.

Lanier, L., and G. Sylvestre.
1971. Epidémiologie du *Lophodermium pinastri* (Schrad.) Chev. Résultats de quatre années d'études à l'aide d'un piège à spores de Hirst. Eur. J. For. Pathol. 1:50-63.

Peterson, G. W.
1965. Dothistroma needle blight of Austrian pine: Infection and control. Plant Dis. Rep. 49:124-126.

Peterson, G. W.
1967. Dothistroma needle blight of Austrian and ponderosa pine: Epidemiology and control. Phytopathology 57:437-441.

Peterson, G. W.
1969. Growth of germ tubes of *Dothistroma pini* conidia positively directed toward stomata of Austrian and ponderosa pine needles. [Abstr.] Phytopathology 59:1044.

Peterson, G. W.
1973. Infection of Austrian and ponderosa pines by *Dothistroma pini* in eastern Nebraska. Phytopathology 63:1060-1063.

Schuck, H. J.
1972. Die Zusammensetzung der Nadelwachse von *Pinus silvestris* in Abhängigkeit von Herkunft und Nadelalter sowie ihre Bedeutung für die Anfälligkeit gegenuber *Lophodermium pinastri* (Schrad.) Chev. Flora 161:604-622.

Schütt, P.
1971. Untersuchungen über den Einfluss von Cuticularwachsen auf die infektionsfähigkeit pathogener Pilze. 1. *Lophodermium pinastri* und *Botrytis cinerea.* Eur. J. For. Pathol. 1:32-50.

Setliff, E. C., and R. F. Patton.
1974. Germination behavior of *Scirrhia acicola* conidia on pine needles. Phytopathology 64: 1462-1464.

Thyr, B. D., and C. G. Shaw.
1964. Identity of the fungus causing red band disease on pines. Mycologia 56:103-109.

5.19 RM-324

September 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-324

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Production of Engelmann Spruce Seed, Fraser Experimental Forest, Colorado: A 5-Year Progress Report

Robert R. Alexander and Daniel L. Noble[1]

Good to heavy seed crops were produced on the Fraser Experimental Forest in Colorado in 4 out of 5 years, with some locations occasionally producing a bumper crop. There was considerable variability in seed crops, however; not all locations produced good crops every good seed year. A tentative relationship was established between 5-year periodic annual seed production, and basal area and average percent live crown of dominant and codominant spruce. Considerably more seedfall data are needed, however, to permit predictions of the frequency of good seed crops and the relationship of average annual quantity of seed produced to stand parameters.

Keywords: *Picea engelmannii*, silvicultural systems, forest seed production.

Prompt establishment of new stands of Engelmann spruce (*Picea engelmannii* Parry) following timber harvest is a major objective in the management of spruce-fir forests in Colorado (Alexander 1974). Good seedbed preparation and favorable environmental conditions are necessary requirements for natural reproduction, but they are of little value without an adequate seed supply. Infrequent good seed crops could restrict the potential for natural regeneration success, and require the use of silvicultural systems that provide a seed supply over long periods of time.

Past studies of Engelmann spruce in the central and southern Rocky Mountains have indicated that intervals between years of good to heavy seed production are sporadic (Alexander 1969, Jones 1967, Ronco and Noble 1971). Knowledge of the frequency of seed crops and the relationship of seed production to stand, tree, and crown characteristics is essential to management of spruce-fir forests with natural reproduction.

A long-term investigation of spruce seed production in high-elevation forests in central Colorado was started in 1968; plots were established by 1970. This Note is a progress report on seed production for the years 1970 through 1974.

[1]*Principal Silviculturist and Associate Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Study Areas

A total of 13 permanent square sample plots, 2 chains on a side, were established on the Fraser Experimental Forest. Plots ranged from 9,120 feet to 11,400 feet in elevation, on a variety of slopes and aspects. Ages of dominants averaged from 192 to 292 years. All stands were dominated by Engelmann spruce. Stand characteristics of each location are shown in table 1.

Methods

Seed Production

Seed production was estimated from seeds collected in ten 1-ft^2 wire seed traps randomly located within each plot. Seed trap contents were collected one or more times each fall beginning in late September, weather conditions permitting, and again the follow-

Table 1.--Stand characteristics, per-acre basis, for dominant and codominant spruce, and total trees

Plot No.	Trees		Basal area		Average diameter		Average height	
	Spruce	Total	Spruce	Total	Spruce	Total	Spruce	Total
	Number		*Square feet*		*Inches*		*Feet*	
1	65	320	84	150	15.4	9.3	78.5	49.5
2	55	250	100	174	1812	11.3	88.0	58.5
3	88	220	133	190	16.7	12.6	60.0	47.0
4	103	323	196	307	18.7	13.2	80.0	59.0
5	95	525	91	255	13.2	9.4	66.0	50.0
6	63	345	101	194	17.2	10.2	85.0	55.0
7	65	365	106	204	17.3	10.1	87.0	52.0
8	65	288	126	213	18.8	11.7	94.0	59.0
9	90	278	102	180	14.4	10.9	84.0	63.0
10	43	283	58	142	15.8	9.6	86.0	54.0
11	35	213	69	138	19.0	10.9	99.0	56.0
12	63	293	77	179	15.0	10.6	79.0	57.0
13	73	203	142	198	18.9	13.4	97.0	68.0

ing spring. All seeds were tested for soundness and recorded as (1) filled or (2) partially filled or empty. Estimates of total quantities of seed produced are based on counts of filled seed only.

Differences in seedfall for locations and years were tested by analysis of variance, with number of filled seeds per trap as the dependent variable. Because of variability in data, seed counts were transformed to $\sqrt{X + 3/8}$.

The following general—and admittedly arbitrary—categories were established to rate seed crops:

Filled seeds (No./acre)	Seed crop rating
<10,000	Failure
10,000 - 50,000	Poor
50,000 - 100,000	Fair
100,000 - 250,000	Good
250,000 - 500,000	Heavy
>500,000	Bumper

Stand, Tree, and Crown Characteristics

Stand inventory information was collected as a basis for relating seed production to some measure of stand density, and/or tree and crown characteristics. Information obtained for individual trees on the plots included:

1. Diameter at breast height to the nearest 0.1 inch (trees 3.6 inches d.b.h. and larger).
2. Total height to the nearest 0.5 foot.
3. Crown class.
4. Species.
5. Average length of live crown to the nearest 0.5 foot (average of four sides).
6. Average width of live crown to nearest 0.1 foot (average of two measurements).

Ages of six to eight dominant spruces were measured for determination of site index (Alexander 1967).

The average annual seed production for each location was plotted against individual and combinations of stand, tree, and crown measures. A computer program was then used to select the independent variables best correlated with seed production. Parameters based only on dominant and codominant spruces were used because numerous studies have shown that coniferous species of these crown classes produce three-fourths or more of the seedfall (Fowells and Schubert 1956, Franklin 1968, Haig and others 1941).

Results and Discussion

Seed Production

Seed was produced in larger quantities and at more frequent intervals (table 2) than previous studies

Table 2.--Production of filled seeds per acre, and percent of total seedfall that was filled

Plot No.	1970 Crop[1]		1971 Crop		1972 Crop		1973 Crop[1]		1974 Crop		5-year average
	Filled seeds	Proportion of total seedfall	Filled seeds	Proportion of total seedfall	Filled seeds	Proportion of total seedfall	Filled seeds	Proportion of total seedfall	Filled seeds	Proportion of total seedfall	Filled seeds
	Thous.	*Percent*	*Thous.*	*Percent*	*Thous.*	*Percent*	*Thous.*	*Percent*	*Thous.*	*Percent*	*Thous.*
1	148	43	44	17	131	24	13	15	209	48	109
2	680	50	107	26	231	26	17	13	340	52	275
3	531	47	200	21	366	24	52	15	109	21	252
4	558	36	152	31	436	32	4	1	362	33	302
5	544	47	96	23	292	28	17	10	422	33	274
6	292	42	161	21	266	27	13	13	436	43	233
7	218	36	170	23	179	24	30	25	274	33	174
8	366	44	192	30	431	32	35	25	222	40	249
9	362	40	335	23	357	24	9	15	244	38	261
10	104	33	148	24	170	32	9	10	122	36	111
11	83	29	252	38	57	18	9	6	109	37	102
12	401	48	61	14	270	32	17	13	135	38	177
13	161	30	754	25	470	18	22	11	540	47	389
Average	342	42	206	32	281	26	19	12	271	38	

[1]Seeds were not collected in fall because of weather conditions.

indicated were likely (Alexander 1969). In general, good to heavy crops were produced 4 out of the 5 years of observation, with some locations producing one or more bumper crops. In the other year, seed crops were generally rated poor to failure.

Seed crops varied considerably by years and locations. Not all locations produced good to heavy crops every good year. Statistical analyses revealed that differences between locations and years, and the locations x years interaction, were all highly significant.

The amount of filled seed produced was related to total seedfall only in a general way. While there was a tendency for the percentage of filled seed to increase as total seedfall increased, no statistical relationship could be established for these data that would account for more than 60 percent of the variability. Another significant finding of this study is that, despite relatively high seed production in 4 years, only about 25 to 40 percent of the total seed collected was filled in those years.

The time of seedfall was also variable between locations within any year and between years at any location. The percentage of total filled seeds collected, by dates, is shown in table 3 for the years when weather conditions permitted collections in both the fall and the following spring. In 1971, one-third to two-thirds of the total filled seeds produced were released by the end of September, while in 1972, the percentage of seeds released by the end of September varied from 7 to 60. By the second week of October 1972, however, 35 to 70 percent of the seeds had been dispersed. In 1974, only nominal amounts of seed were released at most locations by the third week of September, but 25 to 60 percent had been released by the first week in October.

Relation of Seed Production to Stand and Tree Characteristics

Regression analyses of 21 seed production and stand inventory variables resulted in the following equation:

$$\log Y = 9.9814 - 0.0302 X_1 + 0.9162 \log X_2, R^2 = 0.76$$

where

Y = annual average production of sound spruce seeds per acre.
X_1 = average percent of live crown of dominant and codominant spruces.
X_2 = basal area of dominant and codominant spruces per acre.

The equation accounts for about 76 percent of the total variation in the annual average seed production for the 5-year period. The addition of other variables did not significantly improve the precision of the estimate.

The annual average seed production was used as the dependent variable because there was no way to account for annual variation. Furthermore, the independent variables did not change from year to year.

The equation is not intended for predicting average annual seed production; 5 years of seedfall data are insufficient for this purpose. Furthermore, more seed was produced in the period than was expected from past experience. The form of the equations is likely to remain the same, but the coefficients may change with more data.

Table 3.--Percent of total filled seeds released by collection dates (seeds were not collected in fall for 1970 and 1973 crops because of weather conditions)

Plot No.	1971 Crop		1972 Crop			1974 Crop		
	Sept. 27-28	June 6-21	Sept. 26-27	Oct. 10-11	June 18-July 3	Sept. 15-19	Oct. 2-3	June 24-July 10
1	40	60	60	6	34	12	41	46
2	39	61	43	28	29	9	31	60
3	65	35	10	32	58	16	12	72
4	63	37	9	48	43	0	26	74
5	54	46	23	22	55	0	29	71
6	48	52	23	22	55	00	45	55
7	44	56	34	27	39	3	40	57
8	32	68	38	22	40	16	21	63
9	42	58	42	20	38	4	39	57
10	47	53	41	28	31	25	36	39
11	38	62	23	23	54	20	32	48
12	64	36	7	29	64	16	22	62
13	68	32	42	19	39	29	32	39

Management Implications

Dispersal and survival data from past studies indicate that enough viable seeds were produced in 4 out of 5 years in the current study to adequately restock all aspects under a selection or shelterwood cutting alternative, providing seedbed and environmental conditions are favorable. Enough seeds are produced during the 5-year period to adequately regenerate all clearcut openings, except south aspects, if the openings were kept small enough (3- to 5-acre patches or strips no wider than 400 feet) to be within effective seed dispersal distances, and seedbed and environmental conditions were favorable (Alexander 1974). Clearcutting on south slopes is not likely to result in successful natural spruce regeneration regardless of the quantity of seed available, even with good seedbeds, because of unfavorable environmental conditions.[2]

In some years seed crops will be total failures, and even in years of good overall seed production, not all locations will produce good to heavy crops.

In stands to be cut under a selection or shelterwood system, full- and long-crowned dominants and codominants should be retained as leave trees. These trees not only produce the most seed, but are also the most windfirm—an important consideration in partial cutting of high-elevation spruce forests. If trees are marked during a good seed year, it is possible to select the dominants and codominants with the largest number of cones. In years when seep crops are poor, old cones on the ground usually indicate which trees are likely to be the best seed producers.

Guidelines developed for partial cutting in old-growth spruce forests (Alexander 1973) require more leave trees because of wind risk than are needed for seed production. Furthermore, windfall susceptibility of trees and stands is more important than spacing of trees for seed production. If the leave trees blow down, there is no seed source.

In managed stands, the number of trees left at the time of the seed cut under a shelterwood system will vary from 15 to 35 dominants and codominants per acre, depending upon the number of entries in the system, growing stock level selected and site productivity (Alexander and others 1975). This should be more than an adequate seed source for natural regeneration if seedbeds are properly prepared.

This study will be continued indefinitely to provide more information on (1) the quantity of seed produced and frequency of good to heavy seed crops, and (2) the relationship of filled seed production to stand, tree, and crown parameters. Other investigations will include the effect of cone insects on seed production, and the development of a rating system to estimate seed crops from cone counts.

[2]*Noble, Daniel L., and Robert R. Alexander. Environmental factors affecting the regeneration of Engelmann spruce. (Manuscript in preparation at Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.)*

Literature Cited

Alexander, Robert R.
1967. Site indexes for Engelmann spruce in the central Rocky Mountains. U.S. For. Serv. Res. Pap. RM-32, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R.
1969. Seedfall and establishment of Engelmann spruce in clearcut openings: A case history. USDA For. Serv. Res. Pap. RM-53, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R.
1973. Partial cutting in old-growth spruce-fir. USDA For. Serv. Res. Pap. RM-110, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R.
1974. Silviculture of subalpine forests in the central and southern Rocky Mountains: The status of our knowledge. USDA For. Serv. Res. Pap. RM-121, 88 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R., Wayne D. Shepperd, and Carleton B. Edminster.
1975. Yield tables for managed even-aged stands of spruce-fir in the central Rocky Mountains. USDA For. Serv. Res. Pap. RM-134, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Fowells, H. A., and G. H. Schubert.
1956. Seed crops of forest trees in the pine region of California. U.S. Dep. Agric., Tech. Bull. 1150, 48 p.

Franklin, Jerry F.
1968. Cone production by upper slope conifers. U.S. For. Serv. Res. Pap. PNW-60, 21 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Haig, Irvine T., Kenneth P. Davis, and Robert H. Weidman.
1941. Natural regeneration in the western white pine type. U.S. Dep. Agric., Tech. Bull. 767, 98 p.

Jones, John R.
1967. Regeneration of mixed conifer clearcuttings on the Apache National Forest, Arizona. U.S. For. Serv. Res. Note RM-79, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ronco, Frank.
1970. Engelmann spruce seed dispersal and seedling establishment in clearcut openings in Colorado—a progress report. USDA For. Serv. Res. Note RM-168, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ronco, Frank, and Daniel L. Noble.
1971. Engelmann spruce regeneration in clearcut openings not insured by record seed crop. J. For. 69:578-579.

Agriculture—CSU, Fort Collins

ember 1976

USDA FOREST SERVICE
RESEARCH NOTE RM 325

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A "Cartbench" and Track System for Greenhouse Production of Containerized Tree Seedlings

Harvey A. Hiatt[1]

A strong, lightweight "cartbench" and track system was designed to best utilize space, facilitate procedures, and incorporate components involved in greenhouse production of containerized seedlings. This system has worked successfully in three plastic greenhouses at the USDA Forest Service Shelterbelt Laboratory, Bottineau, North Dakota.

Keywords: Cartbench, greenhouse components.

Introduction and Discussion

Greenhouse systems for growing containerized tree seedlings are gaining rapid acceptance.[2] Expenses involved in greenhouse operations where growing conditions are controlled put a premium on the space available for production.[3] One space-consuming component is ductwork for moving large volumes of air for root-pruning and maintaining uniform air temperatures. Conventional stationary greenhouse benches also waste too much lateral aisle space.

To facilitate access to each seedling and best utilize valuable greenhouse space, a strong, lightweight "cartbench" and track system was designed that incorporates an airflow system. Wood-slat bench tops supported by frames made from electrical conduit (fig. 1) ride on a simple wheel and track system (fig. 2). Flanged wheels are inexpensive combine-idler pulleys. Plastic sleeve heating ducts run along the floor below cross braces of the cartbench frame (fig. 3). Individual cartbenches can be rolled apart to create lateral aisles when necessary. Extending the track system beyond removable panels in the end wall gives forklift flexibility for moving seedlings from one greenhouse to another.

The cartbenches were constructed for a specific greenhouse design, heating system, and seedling container, but the whole concept can be adapted to most containerized greenhouse systems. The cartbench was constructed to hold 27 pallets of Spencer Lemaire Rootrainers. Each pallet contained 40 cavities of the "Tinus" (25 in^3) size.

Materials and Procedures

Basically, the cartbenches are wooden racks built from 2- by 2-inch wooden supports bolted to ¾-inch conduit frameworks with ½-inch conduit braces and 4 wheel assemblies made from combine-idler pulleys.

The track system was designed with 2- by 8-inch ties 6 feet long spaced 2 feet apart. The tracks run the length of the greenhouse and extend the width of one cartbench beyond the end wall. Rails were made

[1] *Author is a Forestry Research Technician located at the Station's Shelterbelt Laboratory at Bottineau, in cooperation with North Dakota State University-Bottineau Branch; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Tinus, R. W. Observations and new information on greenhouse container systems. Presented at annual meeting Intermt. Nurserymen's Assoc. Meet.; Missoula, Mont., Aug. 5-7, 1975.*

[3] *Vyse, A. H., and D. E. Ketcheson. 1974. The cost of raising and planting containerized trees in Canada. p. 402-411 Proc. North Am. Containerized For. Tree Seedling Symp. [Denver, Colo., Aug. 1974]. Great Plains Agric. Coun. Publ. 68.*

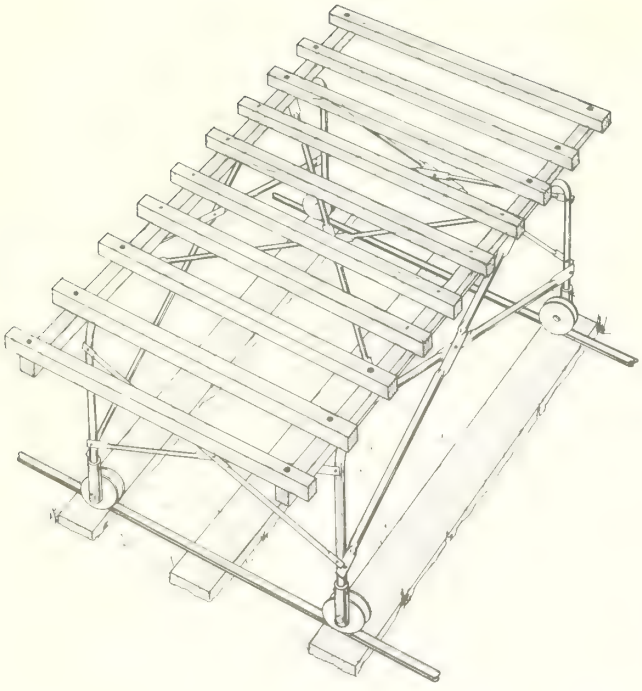


Figure 1.—Cartbench top and conduit frame.

Figure 2.—Simple flanged wheel and track system.

Figure 3.—Heating duct and cartbench crossbraces.

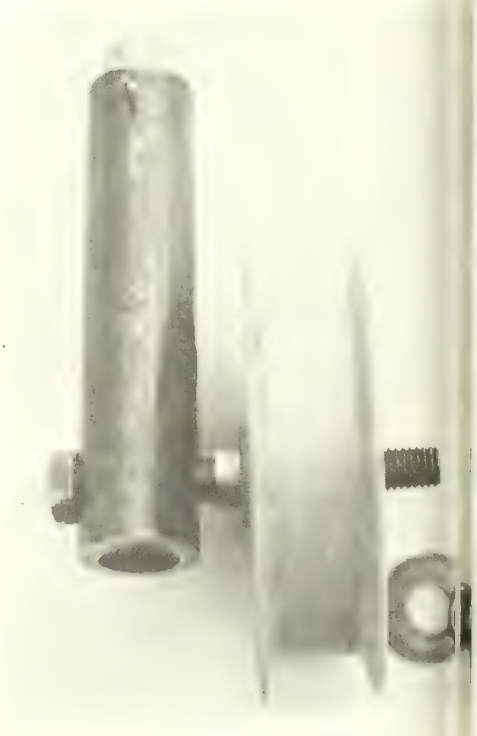


Figure 4.—Wheel assembly.

of ¾-inch heavy duty well pipe. To keep rails parallel, notches in the ties 1⅛ inches wide were sawed ½ inch deep and 67½ inches apart.

The wheel assemblies were made using a 6-inch length of 1-inch heavy duty well pipe (fig. 4). A ½-inch hole was drilled 1 inch from an end, and a 4- by ½-inch machine bolt was inserted for the wheel axle. A 1 9/16 inch length of ½-inch conduit was used as a bushing. The plastic wheel was slipped over the bushing, and a large ½-inch washer was added. A locking washer and nut were tightened, forcing the bushing to shorten and conform to the shape of the well pipe.[4]

The ends and cross points of the cartbench end and cross braces were flattened in a large vise and drilled for ¼-inch bolts. (Cross points for end braces are centered; for cross braces, they are off-centered.) The two pairs of braces were fastened loosely at their cross points with ¾- by ¼-inch stove bolts. Two 10-foot lengths of ¾-inch conduit with 90° bends 2 feet from each end were used for the main side frame and legs.

Jigs were essential to maintain uniformity when the various components of the cartbench were assembled. The cartbench jig was made with two 8-foot lengths of 6- by 6-inch stringers and a 4- by 8-foot sheet of ¾-inch plywood. The plywood was centered on the stringers and nailed in place; ¾-inch holes were drilled through the stringers to hold each leg. Holes were 4 feet apart in width and 5 feet, 11¾ inches apart in length. The jig held the main side frame and legs in place while the cross and end braces were added and secured with 1½- by ¼-inch stove bolts (fig. 5). The cross braces rested on the jig when bolted in place. The main support stringers were clamped in place while being drilled. Two 6- by ¼-inch stove bolts, 53½ inches apart, held them in place. These bolts also held two support rails which were added next. The 6-inch stove bolts also held the top cross braces, which were drilled in place by holding them beneath the holes in the 2- by 2-inch supports. To prevent splitting the two end support rails, 4- by ¼-inch stove bolts were used. The remaining six support rails were drilled to prevent splitting and then nailed with 8-penny box nails. Bolts were then tightened, and the cartbench was removed from the jig. The wheel assemblies were slipped onto the legs, the cartbench was alined on the track, and the wheel assemblies were fastened with cotter pins.

Material costs of $32.57 for constructing a cartbench and $1.98 per foot of track system reflect local January 1976 prices (table 1). Roughly ½ man-day was required to construct a cartbench in the jig.

[4] *Boston Bronze Bushings and aluminum alloy wheels are now available at approximately $20 per cartbench from State Machine Products, P.O. 292, Stevensville, Mont. 59870.*

Figure 5.—Cartbench jig construction and assembly of end and side braces to main side frame and legs.

Table 1.—Material descriptions and costs

Quantity	Part	Purpose	Unit cost	Total cost
CARTBENCH:				
(Electrical conduit)				
2	¾-inch, 120 in.	Main side frames and legs	$ 5.00	
4	¾-inch, 60 in.	Cross braces for main side frame and legs	5.00	
2	¾-inch, 74 in.	Top cross braces	3.08	
4	½-inch, 51 in.	End braces	3.06	$16.14
(Lumber)				
2	2- by 2-inch, 98 in.	Main support stringers	1.96	
10	2- by 2-inch, 54 in.	Support rails	5.40	7.36
(Hardware for frame)				
Stove bolts:				
4	¼-inch, 6 in.	Main support stringer, support rail, and top cross brace fasteners	0.48	
4	¼-inch, 4 in.	End support rail fasteners	.34	
16	¼-inch, 1½ in.	Cross and end brace fasteners	.64	
4	¼-inch, ¾ in.	Cross point brace fasteners	.12	
12	Nails, 8-penny, box, galvanized		.10	
4	Cotter pins, 1/8-inch, 2 in.	Attaching wheel assemblies	.06	
28	Nuts, ¼ inch		.84	2.58
(Hardware for wheel assemblies)				
4	Wheels, plastic, fiberglass-reinforced flanged		3.80	
4	Pipe, heavy duty well, 1-inch, 6 in.		1.10	
4	Bolts, machine, ½-inch, 4 in.	Wheel axle	1.00	
4	Nuts, hex, ½-inch		.24	
4	Washers, flat, ½-inch		.12	
4	Washers, locking		.12	
4	Conduit bushing, ½-inch, 1 9/16 in.		.11	6.49
	Total cost of one cartbench			$32.57
TRACK SYSTEM:				
	Ties, 2- by 8-inch, 6 ft.		2.07	
	Pipe, heavy duty well, ¾-inch, 21 ft.		9.87	
	Total cost of track system per running foot			1.98
JIG:				
(Lumber)				
2	6-by 6-inch, 8 ft.		25.44	
1	Plywood sheet, ¾-inch, 4 by 8 ft.		10.95	
	Total cost of jig construction			$36.39

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

eptember 1976

U S D A FOREST SERVICE

RESEARCH NOTE RM-326

REST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Site Index Curves for Douglas-fir in New Mexico

Carleton B. Edminster[1] and Lewis H. Jump[2]

Presents a figure, table, and FORTRAN subroutine for estimating site indexes for Douglas-fir stands in New Mexico. Site index is expressed as the average height of dominant trees at a breast-height age of 100 years.

Keywords: *Pseudotsuga menziesii*, site index, site quality.

Forest site quality and productive capacity are commonly measured by site index. The only published site index curves for inland Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) apply to the northern and central Rocky Mountains (Brickell 1968).

This Note presents the basic height-age curves needed to classify Douglas-fir stands in New Mexico according to site index.

Source of Data and Analysis

The height-age curves were developed by the anamorphic curve technique described by Chapman and Meyer (1949). Age at breast height (4.5 feet) was used, rather than total age, because it is determined after the initial period of tree establishment. Only dominant trees were included in the sample since they are the most reliable indicators of site productivity. A breast height age of 100 years was selected as the base age for the height-age curves because it most nearly approximates the expected rotation age for managed stands of Douglas-fir in the southern Rocky Mountains.

Total height in feet and breast height age in years were measured on 660 Douglas-fir trees in Colfax and San Miguel Counties of northern and central New Mexico. Trees sampled had to be in the dominant portion of the stand, and appear to be free of injury, disease, and past suppression that would adversely affect height growth. Sample trees ranged in height from 20 to 92 feet, and in breast height age from 26 to 200 years old.

The height-age data were sorted into 10-year age groups, and the average height and age were determined for each group. The average height of each group was plotted over its corresponding average age. The number of trees in each group was used as a weighting factor for each point before a balanced guide curve was fitted to the points.

Before drawing the family of site index curves, we examined the assumption that the height-age curves for different sites are proportional to the shape of the guide curve. We used the method described by Chapman and Meyer (1949). The plot of the coefficient of variation of height over the average age for each group supported the assumption of proportional shape. The assumption that no correlation exists between site quality and tree age of the sampled trees was also examined by plotting site over age. No trend was apparent and the correlation coefficient of site index and tree age was not different from zero, therefore the assumption appears valid.

The site index curves developed from the guide curve are shown in figure 1. Table 1 shows the expected height of trees in the dominant stand at breast height ages 20 to 250 years for site indexes 30 to 120 at base age 100 years.

[1]*Associate Mensurationist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Soil Conservationist, Soil Conservation Service, Raton, New Mexico.*

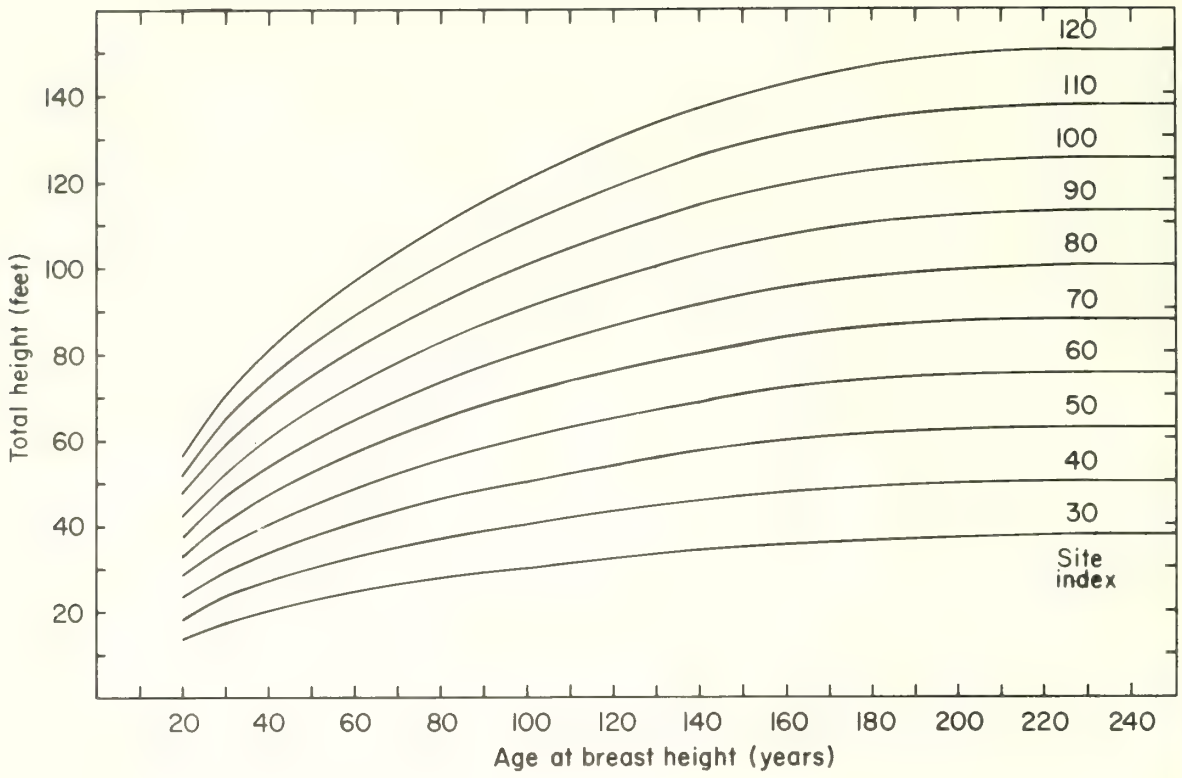


Figure 1.—Site index curves for Douglas-fir in New Mexico. Base age: 100 years, breast height.

Table 1.--Expected height of Douglas-fir trees in the dominant stand

Breast height age (Years)	Site index class									
	30	40	50	60	70	80	90	100	110	120
	Height in feet									
20	14.1	18.8	23.5	28.2	32.9	37.6	42.3	47.0	51.7	56.4
30	17.6	23.4	29.3	35.1	41.0	46.9	52.7	58.6	64.4	70.3
40	20.1	26.8	33.5	40.2	46.9	53.6	60.3	67.0	73.7	80.4
50	22.3	29.7	37.1	44.5	52.0	59.4	66.8	74.2	81.6	89.1
60	24.1	32.2	40.2	48.3	56.3	64.4	72.4	80.5	88.5	96.6
70	25.8	34.4	43.0	51.6	60.2	68.8	77.4	86.0	94.6	103.2
80	27.3	36.5	45.6	54.7	63.8	72.9	82.0	91.2	100.3	109.4
90	28.7	38.3	47.9	57.5	67.0	76.6	86.2	95.8	105.3	114.9
100	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0
110	31.2	41.5	51.9	62.3	72.7	83.1	93.5	103.9	114.3	124.6
120	32.3	43.0	53.8	64.5	75.3	86.0	96.8	107.6	118.3	129.1
130	33.3	44.3	55.4	66.5	77.6	88.7	99.8	110.9	122.0	133.0
140	34.1	45.5	56.9	68.3	79.7	91.0	102.4	113.8	125.2	136.6
150	34.9	46.6	58.2	69.8	81.5	93.1	104.8	116.4	128.0	139.7
160	35.6	47.4	59.3	71.2	83.0	94.9	106.7	118.6	130.5	142.3
170	36.1	48.2	60.2	72.3	84.3	96.4	108.4	120.4	132.5	144.5
180	36.6	48.8	61.0	73.1	85.3	97.5	109.7	121.9	134.1	146.3
190	36.9	49.2	61.5	73.8	86.1	98.4	110.7	123.0	135.3	147.6
200	37.1	49.5	61.9	74.3	86.6	99.0	111.4	123.8	136.1	148.5
210	37.3	49.7	62.2	74.6	87.0	99.4	111.9	124.3	136.7	149.2
220	37.4	49.9	62.3	74.8	87.3	99.7	112.2	124.7	137.1	149.6
230	37.5	49.9	62.4	74.9	87.4	99.9	112.4	124.9	137.3	149.8
240	37.5	49.9	62.4	74.9	87.4	99.9	112.4	124.9	137.3	149.8
250	37.5	49.9	62.4	74.9	87.4	99.9	112.4	124.9	137.3	149.8

Field Application

To determine site index for a Douglas-fir stand, average height and age should be computed from measurements of total height and breast height age of at least six of the taller dominants in the stand (Johnson and Carmean 1953). If the average age of the trees is greater than 250 years, an age of 250 should be used for site index determination. The trees should be growing on the same apparent site as indicated by similar soils, topography, slope, and aspect. Trees selected for measurement should be even-aged (not more than a 20-year spread in age), and show no evidence of disease, crown damage, or excessive sweep or crook. The increment cores removed for aging should indicate no evidence of extended suppression or injury.

Computer Application

The listing of DFSITE, a FORTRAN subroutine to determine site index for a stand, appears below. Input parameters to the subroutine are average height (HT) and average breast height age (AGE) of the sampled trees. The site index of the stand is returned as output parameter SITE. The calling statement to use the subroutine has the form:

```
CALL DFSITE (HT,AGE,SITE)
```

```
 SUBROUTINE DFSITE (HT,AGE,SITE)
 DIMENSION HTSI (25)
 DATA HTSI/4.5,15.0,25.5,31.8,36.4,40.3,43.7,46.7,49.5,52.0,54.3,56
1.4,58.4,60.2,61.8,63.2,64.4,65.4,66.2,66.8,67.2,67.5,67.7,2*67.8/
 TEM = AGE + 0.001
 IF(TEM.GT.230.001)TEM = 230.001
 I1 = (IFIX(TEM)/10) + 1
 I2 = I1 + 1
 A1 = FLOAT(I1-1)*10.0
 A2 = A1 + 10.0
 HTSIA = (HTSI(I1)*(TEM-A2)-HTSI(I2)*(TEM-A1))/(A1-A2)
 SITE = 54.3*HT/HTSIA
 RETURN
 END
```

Literature Cited

Brickell, James E.
1968. A method for constructing site index curves from measurements of tree age and height—its application to inland Douglas-fir. USDA For. Serv. Res. Pap. INT-47, 23 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Chapman, Herman H., and Walter H. Meyer.
1949. Forest mensuration. 522 p. McGraw-Hill Publ. Co., N.Y.

Johnson, Floyd A., and Willard H. Carmean.
1953. Sampling error in estimation of site index. J. For. 51:26-27.

Agriculture—CSU, Fort Collins

September 1976

USDA FOREST SERVICE
RESEARCH NOTE RM-327

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Technique for Slide Preparation of Aphids, Scales, and Insect Genitalia and Larvae

A. D. Tagestad[1]

Describes step-by-step procedures for preparation of permanent slide mounts of several groups of insects, including aphids, scale insects, lepidoptera genitalia, and lepidoptera and sawfly larvae. Necessary equipment and reagents are listed.

Keyword: Insect collections.

Introduction

Many combinations of techniques, equipment, and reagents are suitable for mounting insects on slides (Clarke 1941, Essig 1948, Kozorzhevskaya 1968, and others). This Note does not attempt to review all of them, but outlines an efficient set of procedures for preparing slide mounts of four dissimilar groups, familiar to the author; undoubtedly other insects such as thrips could be added. Differences in handling the groups are minor, as outlined below.

Briefly, the procedure is (1) maceration (soaking) in potassium hydroxide (KOH) to soften body contents; (2) removal of body contents, embryos, scales, and so forth, in 50% alcohol; (3) staining in 50% alcohol into which several drops of a 0.5% solution of mercurochrome has been added; (4) cleanup and dehydration in 95% alcohol; (5) dehydration in 100% alcohol; (6) clearing in clove oil; (7) washing in xylene; (8) mounting in balsam; and (9) ringing. Five to twelve minutes per reagent is generally sufficient; exact times are best determined by experience.

[1] *Biological Technician, located at the Station's Shelterbelt Laboratory in cooperation with North Dakota State University-Bottineau Branch; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Equipment and Reagents

Necessary reagents are 10% solution of KOH; 50%, 95%, and 100% solutions of alcohol; 0.5% solution of mercurochrome; oil of cloves; xylene; mounting media; and a ringing compound. It is advisable to have a dropper bottle for each reagent except the mounting media. Use a standard balsam bottle for the mountant.

Equipment consists of a binocular microscope, hot plate, watch glasses, a spot plate (12 depression), small syringe, eye dropper, small camel's hair brush, slides, cover glasses and cover props, forceps whetted to a fine point, dissecting scissors with points whetted to a needle fineness, fine dissecting needles, miniature knives, and section lifters. Knives and section lifters can be obtained commercially or made by flattening, grinding, and polishing stainless steel insect pins or stainless steel wire. The wire may be obtained from salt-water fishing leaders or from piano wire. Surfaces that touch the specimens must be made as smooth as possible by honing and polishing with a fine abrasive. The tools are mounted in handles made of small-diameter wooden dowels. The type used by physicians as nasal applicators are especially suitable. Fine dissecting needles are made by forcing minutiens, insect pins, or fine sewing needles into handles made of toothpicks or small dowels.

Section lifters are used for transferring specimens from one solution to another, and for teasing out body contents, embryos, and so forth. The syringe is useful for transferring solutions when specimens are left in place. The miniature knives are used for cutting the genitalia from abdominal skins and splitting larval skins. A small camel's hair brush with all but a few bristles removed is useful for manipulating delicate specimens.

Procedures

Dry specimens are soaked in 100% alcohol before maceration in KOH (Post et al. 1968). When possible, select specimens in good condition with minimal damage to appendages. Fresh specimens are most suitable. Avoid using moths with abdomens glued on for genitalia mounts. Unless such a specimen is labeled indicating that the correct abdomen is attached, it should not be used (Clarke 1941).

Step 1.—Soften body contents

Use the same procedures for all insect groups. Heat at about 98°C in a 10% solution of KOH until body contents are soft, or if time permits, soak overnight at room temperature. To preserve natural colors, do not heat excessively; avoid boiling. For aphids and scales, some authors suggest punching a small hole through the integument in an inconspicuous place—generally somewhere on the abdomen—to facilitate the exchange of chemicals after the specimen is softened (Post et al. 1976, Kozorzhevskaya 1968).

Step 2.—Tease out body contents in 50% alcohol

It is not necessary to clean the specimens entirely at this stage; staining, dehydration, and clearing make body contents, scales, and other parts more visible and loosens them. The 50% solution of alcohol is sufficient to break the troublesome surface tension of the water.

Aphids and scales.—Tease out body contents and embryos carefully. If body scales are worked toward the rear, the anal area will usually rupture allowing body contents, embryos, etc. to escape. An alternative is to make a small cut on one side of the abdomen near the tip.

Genitalia.—Remove abdominal contents and loosen abdominal scales.

Larvae.—Cut off the head capsule and clean it out completely by teasing or by patting with a small section lifter. Later dehydration makes the head capsule brittle. Tease out body contents.

Step 3.—Staining

Use the same procedure for all groups. Place specimens in a small amount of a 50% solution of alcohol into which several drops of a 0.5% solution of mercurochrome have been added. Leave in the solution until specimens are pinkish to light red. Do not overstain.

Step 4.—Final cleanup and dehydration

Aphids.—Place in a 95% solution of alcohol and tease out any remaining body contents.

Genitalia.—Place in a 95% solution of alcohol. Clean off remaining scales and abdominal contents. If a female, cut off just ahead of the genital opening. If a male, cut off as close to the genitalia as possible. At this point, position the various parts of the genitalia for most advantageous viewing. This must be done before complete dehydration takes place. Both male and female abdominal skins are compressed laterally.

Larvae.—Place in 95% alcohol. Split the larval skin on one side just above the spiracles. Remove the remaining body contents and flatten the skin. One change is advisable. Small larval skins may be split by inserting a tiny knife inside the skin and rubbing a pin along the sharp edge. Larger skins are split with a fine dissecting scissors. To assure a good lateral view of a proleg, it is sometimes desirable to remove one and mount it separately. In the case of sawfly larvae, remove a mandible, an eyespot, and an antenna from the head capsule and cut away any portion which would be behind the antannae and tend to obscure it. It also may be helpful to pull off the mouthparts and mount separately.

Step 5.—Final dehydration

Aphids and genitalia.—Place in 100% alcohol and let remain for a few minutes. One change of alcohol is advisable.

Larvae.—Larval skin and head capsule are transferred to 100% alcohol for a few minutes.

Step 6.—Clearing

Use the same procedure for all groups. To improve brilliance, transfer the specimens to clove oil and let remain for a few minutes (Essig 1948).

Step 7.—Clearing and washing

Use the same procedure for all groups. Transfer specimens to xylene, and let remain for a few minutes.

Step 8.—Mounting on the slide

Use the same procedure for all groups. Clean a slide and cover glass with a dry cloth towel. Any tiny threads or lint from the towel may be easily blown off the slide or cover glass. Put a small amount of mounting media on the slide. Position the specimen and put the cover glass in place. When several tiny specimens are positioned under the same cover glass, they tend to flow with the mountant when the cover glass is added. To prevent this movement, place the specimens on a thin layer of mounting media, arrange them, and allow a film to form. Then add more mounting media and put the cover glass into place quickly. When cover glass props are used, place the cover glass on them before the mountant is added. If the cover glass props are thick, place a small drop of xylene under the cover glass and add the mountant with an eyedropper. Xylene speeds the flow of the mountant. The space under the cover glass must be filled quickly or the film will melt, allowing the specimens to flow with the mountant, possibly out from under the cover glass. Avoid the use of very thick balsam. Do not store completed mounts on edge when fresh.

Step 9.—Ringing

Use the same procedure for all groups. Ring with a suitable ringing compound to prevent darkening.

Discussion

Canada balsam is the most versatile mounting medium for small insects. Some of its most important qualities are that it gives up air bubbles and air pockets easily, rarely clouds or crystallizes, has a favorable refractive index, is cheap and readily available, and continues to clear after the specimen has been mounted. Some of the new synthetics seem to be suitable but have not been in use long enough to be proven.

Positioning the specimen in the mountant for most advantageous viewing is of the greatest importance. Characters necessary for determination must be in view, and their position from one slide to another must be uniform. If in doubt as to which characters are diagnostic, contact someone familiar with the group you are working on, ideally the taxonomist who will ultimately identify the specimens.

Literature Cited

Clarke, J. F. Gates.
1941. The preparation of slides of the genitalia of lepidoptera. Bull. Brooklyn Entomol. Soc. 36:149-161.

Essig, E. O.
1948. Mounting aphids and other small insects on microscope slides. Pan-Pac. Entomol. 24:9-22.

Hinton, R. E.
1956. Larvae of Tineidae of economic importance. Bull. Ent. Res. 47:251-346.

Kozorzhevskaya, E. F.
1968. Technique of preparing slides for coccid (Homoptora, Coccoidea) determinations. Entomol. Rev. 47(1):146-149.

Post, R. L., David Aarhus, Paul K. Lago, Howard F. Perkins, and Gary L. Thomaason.
1976. Insects—How to collect, mount, identify, preserve and display them. North Dakota Insects, Harold Schaefer Ser. 10, 52 p. (Rev.)

Agriculture—CSU, Fort Collins

September 1976

USDA FOREST SERVICE
RESEARCH NOTE RM-328

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Germination, Survival, and Growth of Lodgepole Pine Under Simulated Precipitation Regimes: A Greenhouse Study

Wayne D. Shepperd and Daniel L. Noble[1]

Amount and distribution of water from 0.0 to 2.0 in/mo affected germination, survival, and growth of lodgepole pine seedlings. Germination increased with increasing amounts of water, but did not appear affected whether water was distributed evenly during the month, or applied once a month. Survival was acceptable when seedlings received 1 in or more of water distributed throughout the month. Overall growth was better at 1.5 or 2.0 in/mo of water.

Keywords: *Pinus contorta*, plant water relations, plant physiology, seed germination.

The climate in which lodgepole pine (*Pinus contorta* Dougl.) grows in the central Rocky Mountains, while warmer and drier than the high spruce-fir zone, is characterized by environmental extremes that can limit regeneration success (Alexander 1974). The amount and distribution of rainfall following snowmelt is a major environmental factor affecting the germination and establishment of lodgepole pine seedlings.

Studies have shown that precipitation early in the growing season is particularly critical to seedling survival, and that up to 90% of the seedling mortality during the first year can be due to drought (Lotan 1964). Indications are that frequent showers of 1 in or more 3 to 4 weeks after germination begins substantially increases lodgepole seedling survival (Lotan 1964, Ronco 1967).

This study was begun to supplement field information on water requirements of lodgepole pine during the first growing season. Seedlings were grown under controlled greenhouse conditions in Fort Collins, Colorado, to measure germination, growth, and initial survival under watering treatments selected to represent the precipitation patterns which can occur following snowmelt in the central Rockies.[2]

[1] *Forestry Research Technician and Associate Plant Ecologist, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Methods and Materials

Seed source.—Lodgepole pine seed used in this study was collected in 1967 at 9,500 ft elevation on the Elk Creek drainage of the Arapaho National Forest near Fraser, Colorado, and stored at 4°C. Germination averaged 67% in 1973.

Soil and seeding.—A fine sand loam of the Darling series, which developed in place from gneiss and schists (Retzer 1962), was collected under a mature spruce-fir stand at 10,500 ft elevation on the Fraser Experimental Forest in central Colorado. Moisture-holding capacities at ⅓ and 15 atmospheres (atm),

[2] *U.S. Weather Bureau records for a 35-yr period (1931-66) from Fraser, Colorado—approximately 5 air miles from the study areas—at 8,500 ft elevation, indicate that average precipitation from June through October varies from 1.75 in in July to 1.00 in in October with a range of 0.50 to 2.50 in covering most years (U.S. Weather Bureau 1931-66). Monthly precipitation is most likely to fall in either several small storms of 0.25 in or less, or in one or two larger storms.*

determined in the laboratory, were approximately 15% and 31%, respectively. The soil was screened through four-mesh hardware cloth, thoroughly mixed, and placed in pots—7 in deep and 6 in in diameter—which were soaked to saturation twice daily for 3 days (d). Twenty seeds were then sown on the surface of the soil in each pot. All pots were again soaked to insure soil moisture was near saturation before watering treatments were begun. A total of 150 pots were prepared.

Experimental design and treatments.—The study consisted of two experiments: In experiment A, pots received 0.0, 0.5, 1.0, 1.5, or 2.0 in of water at the beginning of each month. In experiment B, the same amounts of water were uniformly distributed throughout the month in applications of 0.25 in. Both experiments were randomized block designs, with water at five levels replicated 15 times.

Greenhouse environment.—Environment in the greenhouse at Fort Collins approximated field conditions during the growing season on the Fraser Experimental Forest. Air temperatures were set for a maximum of 70°F during the day and a minimum of 40°F at night. The photoperiod was 16 hours (h) of natural and artificial light. The transition period of temperature changes coincided with light changes. Relative humidity varied from 20% to 30% during the day to 70% to 80% at night. Light intensities inside the greenhouse varied from 3,000 footcandles (fc) on cloudy days to about 5,000 fc on clear days.

Measurements and analyses.—Number of germinating seeds, number of surviving seedlings, and apparent cause of mortality were recorded twice weekly. At the end of 22 weeks, the soil was carefully washed from the roots of all live seedlings, and the top height and root length were measured to the nearest millimeter. The tissue was then ovendried for 24 h at 100°C and weighed to the closest 0.1 mg.

Germination and survival were expressed as percentages of the number of seeds sown per pot; top height, root length, and total dry weight were pot means. Differences due to treatment were tested for significance at $\alpha = 0.05$ by analyses of variance and multiple comparison tests.

Results

Germination.—Average germination for experiment A (watered once a month) ranged from 39.6% for the 0.0-in treatment to 81.0% for the 1.5-in treatment (fig. 1). In experiment B, germination increased linearly from 23.3%, with no water after sowing, to 90.7% at 2.0 in/mo (fig. 1).

Germination rates.—Initial rates of germination were similar in both experiments (fig. 2). In experiment A, however, additional seedlings germinated following each monthly watering. In contrast, most of the seedlings in experiment B had germinated by the seventh week after sowing. Germination continued over a longer period at higher water levels (fig. 2).

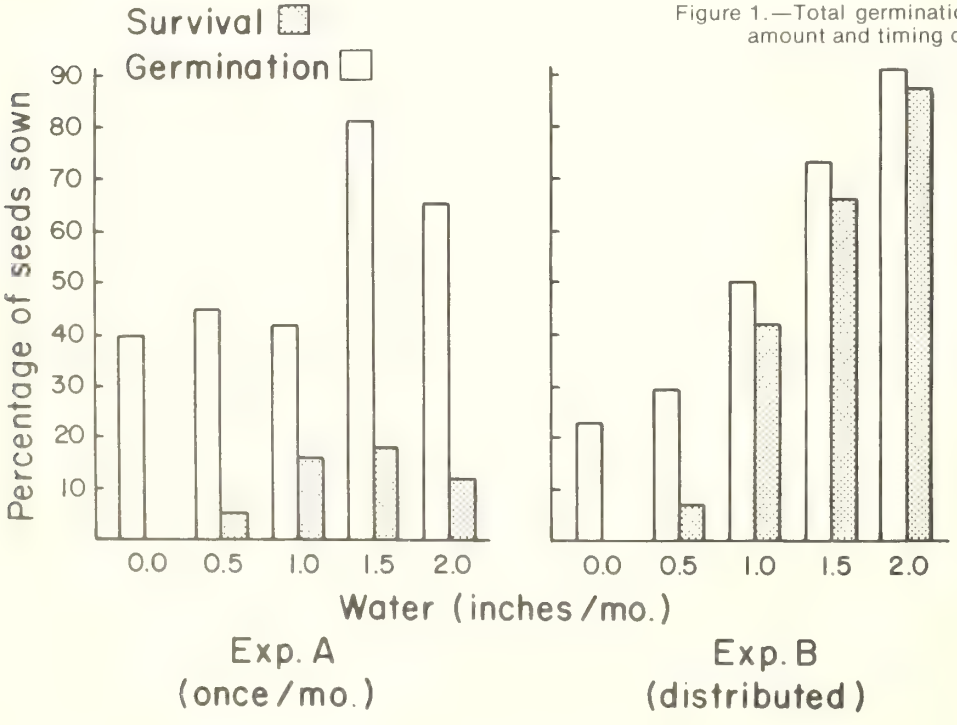


Figure 1.—Total germination and survival in relation to amount and timing of watering treatments.

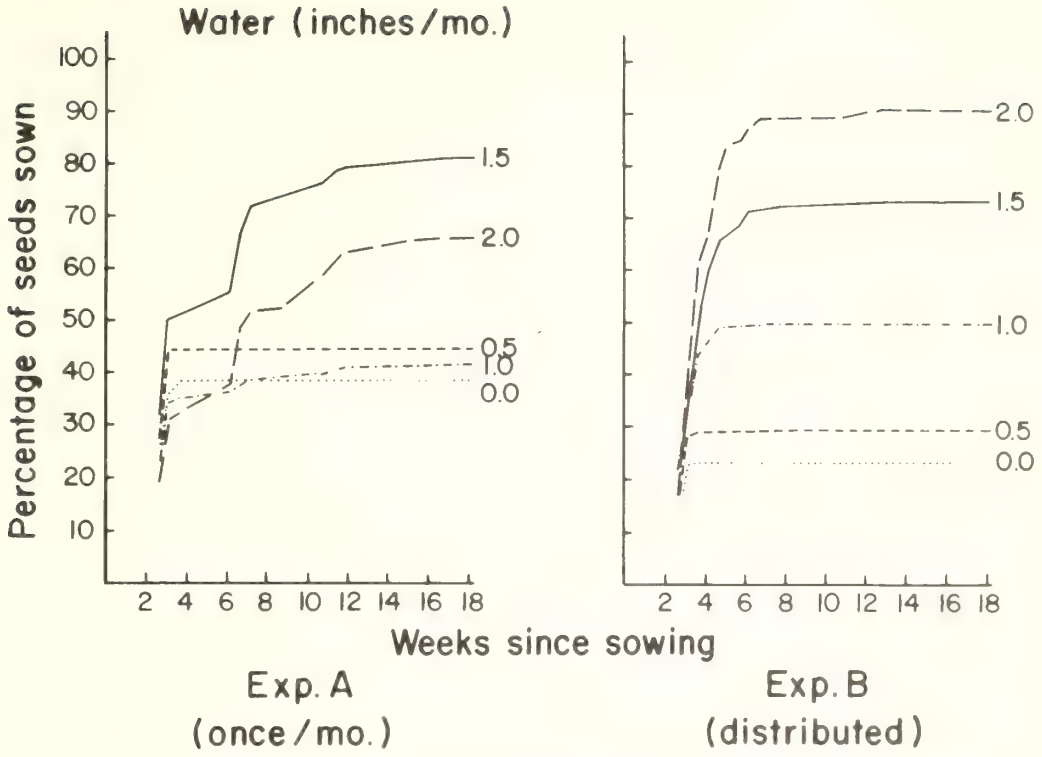


Figure 2.—Rate and pattern of germination in relation to amount and timing of watering treatments.

Survival.—Seedling survival in experiment B was considerably greater than in experiment A at the higher watering levels (fig. 1). Less than 20% of the seeds sown survived at the three highest water levels in experiment A, while 42%, 66%, and 87% of the seeds sown survived in experiment B.

Causes of mortality.—In this study, 99% of the mortality was attributed to three causes—drought, failure to establish, and damping off. Drought was the primary cause of mortality at all watering levels in experiment A, and in all but the 2.0-in treatment in experiment B. In both studies, seedlings of all ages died of drought, but losses were heaviest during the first 3 weeks after germination. However, mortality of seedlings in both studies receiving 0.5 in/mo of water increased again between 13 and 15 weeks after germination. Mortality rates then leveled off, and few seedlings died during the remainder of the study.

Failure to establish, or the inability of a seedling to initiate active growth after germination, was the second most common cause of mortality (25% of the mortality in experiment A, and 20% in experiment B). All mortality from failure to establish occurred within 24 d after germination.

Damping off was not a serious problem in either study; it accounted for 1.2% of the mortality in experiment A and 5.4% in experiment B. All but one of these seedlings died within 7 d after germination.

Seedling growth.—To compare the effect of amount of water on seedling growth, average dry weight, root length, shoot height, and root/shoot ratios were analyzed for the 1.0-, 1.5-, and 2.0-in treatments in both studies. Seedling growth data from the 0.5-in levels were not included in the analysis because of poor survival, but have been retained in table 1 for comparison.

Seedlings in both studies produced significantly more dry weight at the 1.5-in watering level than at the 1.0-in level. In experiment A, seedlings in the 1.5-in treatment were also significantly heavier than those in the 2.0-in treatment (table 1). Although experiments A and B were not compared statistically, distribution of water did not appear to affect the dry weight production of seedlings at levels above 1.0 in/mo of water.

Root lengths were not significantly different among watering levels when seedlings were watered once a month. However, when water was distributed throughout the month, seedlings in the 1.5-in treatment had significantly longer roots than those in the 1.0-in treatment (table 1). Roots of seedlings watered once a month had longer roots than those watered throughout the month.

Shoots of seedlings in experiment B were significantly shorter at the 1.0-in watering level than at the 1.5- and 2.0-in levels. Heights were not significantly different at any watering level for experiment A seed-

Table 1.--Average growth of greenhouse-grown lodgepole pine seedlings watered once a month, experiment A, and at predetermined intervals during the month, experiment B (Means for each variable with common subscripts are statistically homogeneous at α=0.05; 0.5-inch treatment not included in analysis)

Monthly water treatment (Inches)	Dry weight		Seedling height		Root length		Root/shoot ratio	
	A	B	A	B	A	B	A	B
	mg		*mm*		*mm*			
0.5	507.4	724.5	33.4	36.2	239.5	215.0	7.30	5.99
1.0	605.7a	631.4a	37.1	38.5a	238.8	208.4a	6.43	5.45
1.5	766.6b	838.4b	39.8	42.6b	234.4	229.3b	5.96	5.41
2.0	623.2a	757.4b	37.3	43.1b	237.1	221.2ab	6.09	5.16

lings (table 1). Root/shoot ratios were not significantly different in either experiment.

Conclusions

- Mean germination is not drastically affected by the timing of water application (once a month vs 0.25-in increments equally distributed through the month), but is dependent upon the total amount of water received. However, timing of water application does affect the rate and pattern of germination.
- Survival of seedlings will be poor, regardless of the amount of water received, if it is applied only once a month. If water is applied regularly at short intervals, survival increases with increasing amounts of water per month.
- The most critical period for seedling survival appears to be the first 3 weeks after germination. Most seedlings that survived the first 3 weeks and received at least 1.0 in of water distributed through the month lived throughout the studies reported here.
- Dry weight and shoot height increase somewhat with increases in the amount of water received. The effect of water on roots remains unclear.

These studies have been concerned only with precipitation, and do not reflect the many other environmental factors that affect regeneration. In addition, the environment maintained in the greenhouse was more favorable to seedling establishment and growth than most natural conditions. Nevertheless, the results obtained substantiate earlier field observation of Lotan (1964) and Ronco (1967), who suggested that ideal precipitation conditions for germination and survival of lodgepole pine would be at least an inch of rainfall per month, received in small showers throughout the growing season.

Literature Cited

Alexander, Robert R.
1974. Silviculture of subalpine forests in the central and southern Rocky Mountains: The status of our knowledge. USDA For. Serv. Res. Pap. RM-121, 88 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Lotan, James E.
1964. Initial germination and survival of lodgepole pine on prepared seedbeds. U.S. For. Serv. Res. Note INT-29, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Retzer, J. L.
1962. Soil survey of Fraser alpine area, Colorado. Soil Surv. Ser. 1956, No. 20, 47 p. U.S. Dep. Agric., For. Serv. and Soil Conserv. Serv., Colo. Agric. Exp. Stn., U.S. Gov. Print. Off.

Ronco, Frank.
1967. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. U.S. For. Serv. Res. Note RM-90, 8 p. Rocky Mt. For. and Range Exp. St., Fort Collins, Colo.

U.S. Weather Bureau.
1931-66. Climatological data—Colorado section. U.S. Dep. Agric. (1931-1939). U.S. Dep. Commer. (1940-1966).

ber 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-329

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

FEB 28 1977

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Timber Harvesting Increases Deer and Elk Use of a Mixed Conifer Forest

David R. Patton[1]

Timber harvesting in a mixed conifer forest in Arizona resulted in an increase in a mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) use index, while the index remained unchanged in an adjacent uncut area. Herbage production increased 50 pounds per acre, and aspen (*Populus tremuloides*) increased by 321 stems per acre after the timber harvest. Aspen stems and leaves, because of their nutritional value, are important deer and elk foods in the mixed conifer type.

Keywords: *Odocoileus hemionus, Cervus canadensis,* timber harvesting, mixed conifer, wildlife habitat.

Mixed conifer vegetation supports many wildlife species (approximately 90 birds and mammals in Arizona) because it is a vegetatively diverse zone between the higher spruce-fir and lower ponderosa pine forests. It is especially important as summer and fall range for mule deer and elk that use the natural openings and clearcut areas (Reynolds 1966). In Oregon, elk use doubled in openings cut in mixed conifer forest (Edgerton 1972). In the same study, large selectively cut areas had lower deer use than uncut stands. There are no comparable research results for the mixed conifer type in the Southwest except for aspen stands.

Aspen stands are generally associated with mixed conifer and provide large amounts of herbaceous vegetation for grazing animals. Deer use these stands more than the adjacent forest, but there is no difference in elk use (Reynolds 1969).

Precipitation on high-elevation forested watersheds provides runoff for domestic and agricultural use in lower areas. Recent studies have shown that the mixed conifer vegetation type has a higher water yield than other types in the Southwest (Ffolliott and Thorud 1975), and additional water can be obtained from the type by reducing tree overstory (Rich and Thompson 1974). Thus timber harvesting to produce more water can be expected to increase. Mixed conifer vegetation in Arizona, Colorado, and New Mexico covers about 2 million acres; Arizona's portion is between 250,000 and 300,000 acres (Jones 1974).

Timber harvesting changes the attributes of habitat, both structurally and spatially. These changes are sudden, and resident animals are immediately presented with new environmental conditions that could have either positive or negative effects. Managers need to know how wildlife responds to habitat changes from timber harvesting so they can recommend alternative types of cutting to enhance or preserve habitat for food and cover. This Note reports the results of a 7-year study (1969 to 1975) to determine the effects of timber harvesting in Southwestern mixed conifer on mule deer and elk use.

Study Areas

The study areas, one 504 acres (treatment) and the second 328 acres (control), were located on the Apache National Forest approximately 50 miles south of Springerville, Arizona. Relatively steep slopes and

[1]*Principal Wildlife Biologist, located at the Station's Forest Hydrology Laboratory at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

sharp, narrow drainages are characteristic of both watersheds. The main aspects are southeast and northwest. Elevations range from 8,800 to 9,300 feet. Precipitation records indicate about 30 inches a year. April, May, and June are the dry months, receiving 6 percent of the total precipitation. The growing season (July to September) gets 30 percent of the annual precipitation.

Mixed conifer vegetation in the study areas includes a relatively large number of tree species: Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), corkbark fir (*Abies lasiocarpa*), ponderosa pine (*Pinus ponderosa*), southwestern white pine (*Pinus strobiformis*), and quaking aspen. Browse species include aspen, boxleaf (*Pachistima myrsinites*), snowberry (*Symphoricarpos palmeri*), and oak (*Quercus gambelii*). Arizona fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), and nodding brome (*Bromus anomalus*) are the characteristic grasses. Common forbs present are lupine (*Lupinus argenteus*), western yarrow (*Achillea lanulosa*), and cinquefoil (*Potentilla hippiana*). A general description of the mixed conifer type and factors influencing its silviculture has been published in a status-of-knowledge paper by Jones (1974).

Two harvesting methods were used: selection cutting and overstory removal. In the selection area, emphasis was on removing single trees and small groups, and salvaging defective trees. In the overstory removal area, trees were harvested down to a 10-inch diameter limit, although some trees larger than 10 inches were left, especially along roads and meadows. Occasionally, large trees were also left as perches and feeding sites for songbirds.

Methods

The timber inventory design was a systematic point sample using a Basal Area Factor prism of 25. There were 182 points in the watershed to be harvested and 127 points in the control. Timber was removed in 1972. Aspen stems were counted on 0.003-acre circular plots at each inventory point once before (3 years) and once after (2 years) the timber harvest. On these same plots, grasses and forbs were clipped on a subplot of 9.6 square feet. Aspen stems and leaves were collected in July and October to determine protein, calcium, and phosphorus content.

Deer and elk fecal pellets were counted in both watersheds once a year during the first week in September. The plots used were the same as for aspen stem counts. Pellets were counted in September before falling aspen leaves made them difficult to find. Pellet counts were converted to deer and elk use indexes by dividing groups per acre by the defecation rate (13 groups per day).

Timber Harvest Effects

In terms of tree density, the overstory removal (302 acres) was a more severe treatment than selection (114 acres). Basal area was reduced only from 197 to 135 square feet per acre by selective cutting. The remaining basal area was contained in 152 trees per acre over 7 inches d.b.h. Overstory removal, in contrast, reduced basal area from 179 to 29 square feet per acre. Although this was a drastic reduction (84 percent), it was not uniform. Within the area there remained 22 patches of trees from ⅓ to 3½ acres. Thus deer and elk using the overstory removal area would be 750 feet or less from cover.

Preharvest deer use was similar on both watersheds. Deer use gradually increased in the cut watershed from 1973 to 1975, while use stayed the same for 2 years and then declined in 1975 in the uncut area. Elk use of both watersheds was low throughout the study period, but increased slightly in the treated area after the timber harvest. Index of days of use per acre, determined by dividing pellet groups per acre by the defecation rate (13 groups per day), for deer and elk in the cut and uncut watershed was as follows:

	Deer use		Elk use	
	Cut	Uncut	Cut	Uncut
1969	3.6	4.2	0.2	0.2
1970	1.4	1.4	.4	0
1971	.7	1.2	.2	.4
1973	2.8	2.2	.8	.6
1974	3.5	2.2	1.4	.8
1975	4.2	1.6	1.8	.8

No count was made in 1972 because timber harvest was in progress.

Numbers of aspen stems increased on the cut watershed from 494 to 815 per acre 2 years after the timber harvest. Aspen stems and leaves in October rank from good to excellent for protein, phosphorus, and calcium:

	Stems	Leaves	
		Live	Fallen
	– – –	(*Percent*)	– – –
Protein:			
July	5.2	12.0	—
October	9.8	12.6	4.0
Phosphorus:			
July	.22	.40	—
October	.29	.57	.20
Calcium:			
July	.63	.77	—
October	.68	.73	.17

These rankings were determined from ranges of nutrient percentages (Urness 1973). Herbage estimates made 3 years before and 2 years after the

timber harvest show an increase of about 50 pounds per acre:

	1969 (Before)	1974 (After)	Change
Forbs	84	122	+38
Grasses	16	29	+13
Total	100	151	+51

Conclusions and Management Implications

The use index indicates beneficial effects for deer following a timber harvest in an Arizona mixed conifer forest. These findings follow the same trend as reported for a ponderosa pine forest (Patton 1974). Evidently, the same factors of food, cover, and diversity resulting from timber harvesting in ponderosa pine are also at work in the mixed conifer. Elk also responded to the timber harvest, but use was less than for deer.

An increase in the use index does not necessarily mean there was an increase in animal numbers. Changes brought about by timber harvesting could entice deer and elk to move from the surrounding uncut forest. If the changes are beneficial, however, animal numbers should increase over time. Results from this study add more weight to the premise that timber harvesting is beneficial to deer and elk as long as sufficient protective cover remains.

When recommending timber harvesting for habitat improvement, managers must be concerned with **how much vegetation to leave for cover,** not just **how much timber to remove to stimulate forage production.** The balance between the two factors must be determined before proper management guidelines can be established.

Since aspen is an important source of energy for deer and elk, every effort should be made to regenerate old aspen stands to make twigs and leaves available for food. Timber harvesting is one way to get aspen to sprout. More sprouting probably can be achieved, however, by the judicious use of fire after the timber harvest (Patton and Avant 1970).

Literature Cited

Edgerton, P. J.
1972. Big game use and habitat changes in recently logged mixed conifer forest in northeastern Oregon. Proc. 52d Annu. Conf. West. Assoc. State Game Fish Comm., Portland, Oreg., p. 239-246.

Ffolliott, P. F., and D. B. Thorud.
1975. Water yield improvement by vegetation management, focus on Arizona. U.S. Dep. Comm., Nat. Tech. Inf. Serv., Arlington, Va. PB-246-055.

Jones, John R.
1974. Silviculture of southwestern mixed conifers and aspen: The status of our knowledge. USDA For. Serv. Res. Pap. RM-122, 44 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Patton, David R.
1974. Patch cutting increases deer and elk use of a pine forest in Arizona. J. For. 72(12):764-766.

Patton, David R., and Herman D. Avant.
1970. Fire stimulated aspen sprouting in a spruce-fir forest in New Mexico. USDA For. Serv. Res. Note RM-159, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Reynolds, Hudson G.
1966. Use of openings in spruce-fir forests in Arizona by elk, deer, and cattle. U.S. For. Serv. Res. Note RM-66, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Reynolds, H. G.
1969. Aspen grove use by deer, elk, and cattle in southwestern coniferous forests. USDA For. Serv. Res. Note RM-138, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Rich, Lowell R., and J. R. Thompson.
1974. Watershed management in Arizona's mixed conifer forests: The status of our knowledge. USDA For. Serv. Res. Pap. RM-130, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Urness, Philip J.
1973. Deer nutrition in Arizona chaparral and desert habitats. Part II: Chemical analyses and in vitro digestibility of seasonal deer forages. Spec. Rep. 3, p. 39-52. Ariz. Game and Fish Dep., and U.S. For. Serv., Rocky Mt. For. and Range Exp. Stn.

Agriculture—CSU, Fort Collins

ber 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-330

OREST SERVICE
DEPARTMENT OF AGRICULTURE
FEB 28 1977
KY MOUNTAIN FOREST AND RANGE EXPERIMENT

Cottontail Responses to Forest Management in Southwestern Ponderosa Pine

Ralph Costa, Peter F. Ffolliott, and David R. Patton[1]

Cottontail populations increased only in a clearcut area, where ponderosa pine regeneration provided sufficient food and cover. Windrowing slash and encouraging dense tree regeneration or shrubby and herbaceous undergrowth should improve cottontail habitat under shelterwood and group selection systems also.

Keywords: Wildlife habitat, *Pinus ponderosa* type, *Sylvilagus* spp.

The cottontail (*Sylvilagus* spp.) has been extensively studied in other regions, but its relationship to the ponderosa pine (*Pinus ponderosa*) forests of the Southwest has received little attention. Within these forests, cottontails are often harvested as a "secondary" resource by hunters pursuing other game species. Thus, the cottontail should be considered for fuller habitat management. Because the effects of various silvicultural methods applied in ponderosa pine forests are unknown, this study was initiated to determine cottontail responses to various forest management practices.

Study Areas

Beaver Creek Watersheds

Data were obtained from six watersheds on Beaver Creek, located on the Coconino National Forest, approximately 30 miles south of Flagstaff in north-central Arizona (fig. 1). Elevations range from 6,800 to 8,000 feet; drainage is to the south and southwest. Slopes vary from 0 to 10 percent and soils are of volcanic origin (Williams and Anderson 1967). Overstory vegetation consists of ponderosa pine, alligator juniper (*Juniperus deppeana*), and Gambel oak (*Quercus gambelii*), while perennial grasses, forbs, and shrubs comprise the understory.

Management treatments on the six watersheds are described in table 1.

Heber Watersheds

Data were also gathered on four watersheds near Heber on the Apache-Sitgreaves National Forest in east-central Arizona (fig. 1). Watersheds 3 and 4 are located 6 miles southwest of Heber; watersheds 1 and 2 are 5 miles farther southwest. The watersheds range in elevation from 6,900 to 7,700 feet. Slopes vary between 0 and 40 percent, and soils are of sandstone origin. Overstory vegetation includes ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), alligator juniper, and Gambel oak; understory vegetation consists of perennial grasses, forbs, and shrubs.

Timber on all four watersheds had been harvested twice by group selection. At the time of this study, watershed 1 (20 acres) contained 68 square feet of ponderosa pine basal area per acre, 6 square feet of Douglas-fir and white fir, and 3 square feet of Gambel oak. On watershed 2 (28 acres), ponderosa pine accounted for 67 square feet of basal area per acre, while Douglas-fir, white fir, and Gambel oak

[1]*Costa is Research Assistant, and Ffolliott is Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Patton is Principal Wildlife Biologist, located at the Station's Forest Hydrology Laboratory at Tempe in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Table 1.--Management treatments on Beaver Creek watersheds

Watershed no. and management treatments	Size	Description
	Acres	
8 Silvicultural improvement	1,802	Residual densities of 60 sq ft of basal area in size classes 10 in d.b.h. and less, 70 sq ft in 12-22-in d.b.h. classes; stands averaging 24 in d.b.h. and larger cut in a shelterwood system.
10 Big-game improvement	571	Irregular openings (1 to 10 acres); logging debris piled and, in some cases, burned; timber in leave areas cut in similar manner as watershed 8.
12 Timber cleared	455	All timber clearcut; logging debris piled in long, narrow windrows 100 ft apart.
13 Group selection	867	Residual density of 99 sq ft of basal area per acre; logging debris piled and, in some cases, burned.
14 Irregular strip shelterbelt	1,267	One-third of the area cleared in irregular strips averaging 60 ft wide; intervening leave strips thinned to 60 sq ft of basal are per acre; logging debris piled and burned; Gambel oak less than 15 in d.b.h. left for mast.
17 Severe thinning	299	Residual density of 30 sq ft of basal area per acre; logging debris piled in windrows; Gambel oak less than 15 in d.b.h. left for mast.

totaled 2 square feet. Timber densities on watershed 3 (60 acres) were 58 square feet of ponderosa pine basal area per acre, 8 square feet of Gambel oak, and 0.5 square foot of alligator juniper. Watershed 4 (61 acres) supported 89 square feet of basal area of ponderosa pine per acre, 7 square feet of Gambel oak, and 2 square feet of alligator juniper.

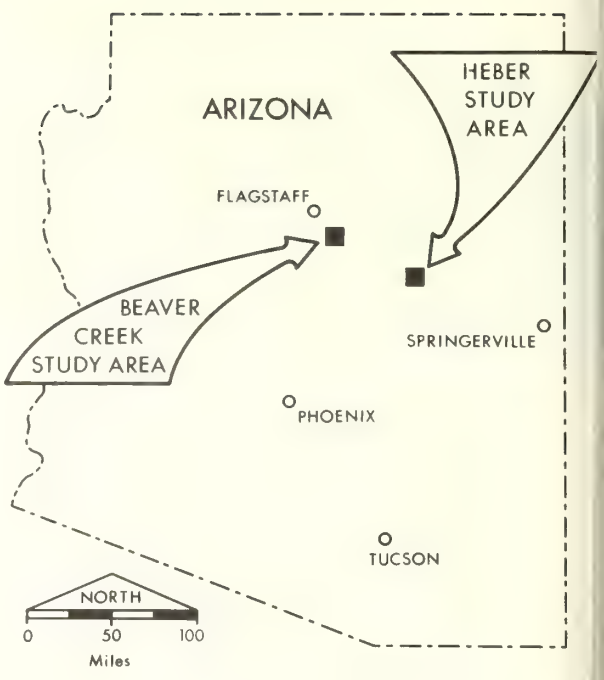


Figure 1.—Location of study areas.

Methods

Individual fecal pellets were counted to determine the habitat preferences of rabbit populations. On the Beaver Creek watersheds, a systematic sampling design with multiple random starts was used. Primary sampling units consisted of 1/100-acre circular plots (11.8 feet in radius) arranged in lines perpendicular to the major drainage. The number of plots per watershed varied from 145 to 200. On each of the Heber watersheds, 30 clusters of three 1/100-acre plots similarly arranged in lines perpendicular to the drainage were sampled.

Cottontail pellets were counted and cleared from all plots on the 10 watersheds during the spring and fall of each sample year. Sampling started in 1972 and was terminated in 1975.

The mean number of pellets per 1/100-acre plot for each watershed was used as a measure of cottontail response to the forest management practices evaluated. Statistical inferences were tested at the 0.10 alpha level. A two-tailed analysis of variance was used to test for differences among cottontail responses for each sampling period. If the F test was significant, Tukey's w-procedure was implemented to assess which of the treatment means was significantly different.

Results and Discussion

On Beaver Creek, cottontail populations were not affected by stripcuts, shelterwood cuts, patchcuts, or group selection harvesting. Populations increased after clearcutting. During the study, the mean number of pellets on the treatments, other than the clearcut, averaged 0.36 per plot, and ranged from 0.11 to 0.90. The number of pellets on watershed 12 averaged 12.4 per plot, ranging from 7.4 to 17.1.

The increased number of cottontail pellets on the clearcut area was probably due to increases in both cover and herbage production. Native herbaceous and shrubby plants increased an average of 504 pounds per acre in the initial 5 posttreatment years (Brown et al. 1974). Apparently, the other treatments did not provide the proper distribution or large enough quantities of cover and food for increased cottontail use. The clearcut contained abundant cover, provided by slash piles and numerous thickets of Gambel oak sprouts (fig. 2). Various investigators have suggested that slash and brush piles provide necessary cover for cottontails (Haugen 1942, Bowers 1954, Redd 1956, Kundaeli and Reynolds 1972, Perkins 1974).

While increased cover was probably the most important factor in the positive response of cottontails on watershed 12, the increased herbage production and subsequent food supply created by clearcutting was undoubtedly beneficial. Other investigators have found that the desert cottontail consumes a large variety of vegetation (Fitch 1947, Turkowski 1975). The cottontail's ability to adapt to different food sources was evident during the winter months of 1974 and 1975 when accumulated snow often covered a majority of the grasses and forbs. During these months, casual observations indicated that Gambel oak sprouts were used relatively heavily as a food source.

On the Heber study area, cottontail populations were significantly higher only on a 4-acre corner of watershed 1 that had roughly 50 percent more reproduction about 4½ feet tall (933 stems per acre vs. 642, fig 3). Although this area contained only 18 of the 90 sample plots, these plots contributed 75 and 87 percent of the total pellet counts in 1974 and 1975, respectively. Dense ponderosa pine regeneration seemed to provide sufficient summer and breeding cover, as well as food, for increased cottontail use. Other investigators have stated, however, that young conifer stands lose their effectiveness as cover at about 10 years of age (Allen 1939, Webb 1949).

The positive responses of cottontails on Beaver Creek watershed 12 and on Heber watershed 1 could be attributed to the increase in yearlong cover. Although it has been suggested that winter cover is more important than summer cover for cottontails in the ponderosa pine forest (Lowe 1975), the general absence of any sufficient cover in the typical open ponderosa pine forest is apparently the limiting factor.

Management Implications

Although there are various alternatives for managing Arizona ponderosa pine forests, apparently only one system, clearcutting, has a long-term beneficial effect on the desert cottontail. Cottontail populations during the summer increased when dense ponderosa pine reproduction was reestablished.

When managing the ponderosa pine for timber production, which is probably best accomplished by a shelterwood or group selection system (Schubert

Figure 2.—Windrowed slash and Gambel oak thickets on Beaver Creek watershed 12, the clearcut study area.

Figure 3.—Dense stand of ponderosa pine reproduction on Heber watershed 1.

1974), cottontail numbers can be increased by encouraging dense natural or artificial regeneration.

If clearcutting is used to increase forage production, cottontail use can be increased by windrowing the slash and encouraging herbaceous and shrubby growth through soil preparation procedures.

A ranked response model for evaluating alternative forest management practices with respect to cottontail use was developed from the results of this study (table 2). While not complete, the examples presented may aid a manager in identifying and evaluating potential cottontail habitat within ponderosa pine forests.

Table 2.--Ranked response model for cottontail in ponderosa pine forests

Management system and residual basal area (sq ft/ acre)	Ponderosa pine reproduction[1]	Slash	Habitat potential (ranked response)
Clearcut			
0	High	Windrowed	+
	High	Cleared	+
	Low	Windrowed	++
	Low	Cleared	0
Group selection with silvicultural thinning			
30	High	Windrowed	+
	High	Cleared	+
	Low	Windrowed	0
	Low	Cleared	0
60-70	High	--	+
	Low	--	0
125	Low	--	0
Strip shelterwood with silvicultural thinning			
60	High	Windrowed	+
	High	Cleared	+
	Low	Windrowed	0
	Low	Cleared	0
Shelterwood with silvicultural thinning			
65	High	--	+
	Low	--	0
Patchcut (1/5 of area) Silvicultural thinning			
	High	Piled	+
	High	Cleared	+
	Low	Piled	0
	Low	Cleared	0

[1]"High" reproduction is 900 stems per acre.

Literature Cited

Allen, Durward L.
1939. Michigan cottontails in winter. Wildl. Manage. 3:307-322.

Bowers, G. L.
1954. An evaluation of cottontail rabbit management in Pennsylvania. North Am. Wildl. Conf., 19:358-386.

Brown, Harry E., Malchus B. Baker, Jr., James J. Rogers, and others.
1974. Opportunities for increasing water yields and other multiple use values on ponderosa pine forest land. USDA For. Serv. Res. Pap. RM-129, 36 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Fitch, Henry S.
1947. Ecology of a cottontail rabbit (*Sylvilagus auduboni*) population in central California. Cal. Fish and Game 33:159-184.

Haugen, Arnold O.
1942. Cottontails need more cover. Mich. Conserv. 11:8-11.

Kundaeli, John N., and Hudson G. Reynolds.
1972. Desert cottontail use of natural and modified pinyon-juniper woodland. J. Range Manage. 25: 116-118.

Lowe, Philip O.
1975. Potential wildlife benefits of fire in ponderosa pine forests. MS Thesis, Univ. Ariz., Tucson. 131 p.

Perkins, Carrol J.
1974. Silvicultural practice impacts on wildlife. Proc. Timber-Wildl. Manage. Symp. Miss. Acad. Sci. Occas. Pap. 3, p. 43-48.

Redd, John Burton, Jr.
1956. Abundance and distribution of the cottontail rabbit as affected by land use. MS Thesis, Vir. Polytech. Inst., Blacksburg. 80 p.

Schubert, Gilbert H.
1974. Silvicultural of southwestern ponderosa pine: The status of our knowledge. USDA For. Serv. Res. Pap. RM-123, 71 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Turkowski, Frank J.
1975. Dietary adaptability of the desert cottontail. J. Wildl. Manage. 39:748-756.

Webb, Cleon E.
1949. Suggestions for the development of cottontail rabbit areas. Paper presented at the Eleventh Midwest Wildl. Conf. Dec. 15-17, 1949, Madison, Wis., 5 p.

Williams, John A., and Truman C. Anderson, Jr.
1967. Soil survey of Beaver Creek area, Arizona. USDA For. Serv., Soil Conserv. Serv., and Ariz. Agric. Exp. Stn. 75 p. U.S. Gov. Print. Off., Wash., D.C.

Agriculture—CSU, Fort Collins

ber 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-331

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
FEB 27 1977

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Temperatures, Growth, and Fall of Needles on Engelmann Spruce Infested by Spruce Beetles

J. M. Schmid[1]

Needle temperatures of Engelmann spruce (*Picea engelmannii* Parry) trees infested by spruce beetles (*Dendroctonus rufipennis* (Kirby)) were occasionally significantly higher than those of noninfested spruce between 12 noon and 3:15 LST. However, the mean needle temperatures of infested and noninfested trees were usually within 1°C of each other. Needle temperatures were significantly higher on the east sides than on the west sides of both infested and noninfested spruce in the morning and higher on the west sides in the afternoon. Infested trees produced new needles the summer following beetle attack. Most needles were stripped from the infested trees during thunderstorms two summers after beetle attack. The effects of needle temperatures, new growth, and foliage discoloration on the remote sensing of infested trees are briefly discussed.

Keywords: *Dendroctonus rufipennis, Picea engelmannii,* spruce, temperatures.

Aerial detection of spruce trees (*Picea engelmannii* Parry) infected by spruce beetles (*Dendroctonus rufipennis* (Kirby)) is difficult because few needles discolor during the summer of beetle attack. Visual evidence of infested trees is limited to sawdust in the bark and around the bases of the trees—characteristics certainly invisible from the air. Needles usually turn a greenish yellow and fall about a year after attack, although some trees may remain green until the fall of the second year (Massey and Wygant 1954). When a large group of infested trees has discolored or lost a substantial portion of their needles so that they appear like skeletons, they are more easily detected by aerial observers. Scattered individual trees may remain undetected, however, because these foliar changes are subtle.

When Heller et al. (1968) reported that the needles of beetle-infested ponderosa pines (*Pinus ponderosa* Lawson) may be up to 6°C warmer than those of noninfested trees, a previsual solution to the detection problem seemed possible. If similar temperature differences existed between infested and noninfested spruce, thermal imagery might be used to detect the infested spruce prior to their foliar color change and thus give earlier notice of an infestation. Therefore, a study was initiated to determine if the needle temperatures of infested and noninfested spruce differed throughout the period of beetle development in the infested trees (approximately 2 yrs). The crowns of the trees were also observed for the growth, discoloration, and fall of needles to determine other characteristics that might be helpful in detecting infested trees.

[1]*Entomologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Methods

In July 1972 three beetle-infested and three noninfested Engelmann spruce, *Picea engelmannii* Parry, trees were selected for needle temperature measurement on Green Mountain (elevation 3200 m), about 14 km southwest of Encampment, Wyoming. Two subalpine firs, *Abies lasiocarpa* (Hooker) Nuttall, were also monitored. The trees formed a natural circle around a small opening in the forest canopy, which facilitated temperature recordings at a central point.

Two 30-gage copper-constantan thermocouples (accuracy = $\pm$ 0.5°C) were inserted in needles in each tree in the upper one-third to one-half of the crown. One thermocouple was placed on the east side of the crown, the other on the west side. Each thermocouple was inserted in an outermost needle on the upper side of a branch. The same needles were used for temper-

ature measurements until they fell off the branch or it was impossible to retain the wire in the needles.

During 1972 and 1973, the 16 thermocouples (12 from spruce and 4 from fir) were connected to a 16-point strip-chart recorder. When operating, the recorder inscribed a temperature measurement every 30-40 s so that the temperature of a specific needle was recorded about every 8-10 min. In 1974, the thermocouples were connected to a potentiometer without an automatic printout device, and the 16 readings were recorded manually about every hour during periods of observation.

Temperatures were recorded during daylight hours at about 2-week intervals in September and October of 1972; June, July, August, and September of 1973; and June, July, and August of 1974. During recording sessions at least one day of temperatures under relatively cloudless skies was obtained.

Simultaneously with needle temperature recordings, the temperature and humidity of the air at treetop and at 1.5 m aboveground were recorded on charts on hygrothermographs. The hygrothermograph at treetop level was positioned under a plywood platform on the top of a tower, while the hygrothermograph, near ground level, was placed in the shade of several large spruce. A pyranograph at treetop level recorded the intensity of the sun's radiation and, indirectly, the relative cloudiness.

Temperatures were not recorded during nighttime hours. Weber (1969) noted that nocturnal temperature differences were not likely between beetle-infested and noninfested ponderosa pines. Denny et al. (1971) stated that maximum diurnal temperature differences developed between noon and 3 p.m. Since the temperatures of infested and noninfested spruce became nearly identical under general cloud cover, it seemed unlikely that they would become significantly different when the foliage was free from direct solar radiation.

Mean temperatures of infested and noninfested spruce for 8-10 minute periods in 1972 and 1973, and for hourly readings in 1974, were compared by the unpaired "t" test. Differences were considered significant at the .05 level.

Tree Characteristics

Diameters of the infested trees at breast height were 47.5, 43.0, and 40.0 cm, while the noninfested trees were 32.0, 41.0, and 38.5 cm. The trees ranged in height from 22 to 25 m. The trees were attacked in July 1972 by spruce beetles; the density of beetle attacks averaged 4 per 900 cm^2 (30 cm x 30 cm bark samples) at breast height. Attack densities were determined in August 1974 after temperature recordings had ceased. All infested trees had blue stain but the amount varied from streaks to complete coverage of the area exposed under the bark.

Results and Discussion

Needle Temperatures

Mean needle temperatures of infested trees were not consistently warmer than noninfested trees; being warmer only on certain days. Infested trees were 2.5-5°C warmer during specific times on June 21, 22, July 17, 31, and August 2, 1973. Significant temperature differences generally occurred between 12 noon and 3:15 p.m. (1200-1515 hrs) local time (table 1).

Table 1.--Mean temperatures (°C) of three infested and three noninfested Engelmann spruce on a typical August day when significant differences developed[1]

Local sun time	Infested	Non-infested	Difference	"t"
0850	11.6	14.0	-2.4	[2]3.73*
0900	12.3	13.2	-0.9	2.00
0930	13.2	15.2	-2.0	2.41*
0950	15.4	14.7	+0.7	0.83
1000	15.8	14.6	+1.2	1.41
1030	14.9	13.2	+1.7	2.46*
1040	15.1	15.8	-0.7	0.92
1100	14.6	15.4	-0.8	1.62
1110	15.4	14.6	+0.8	1.79
1130	15.8	15.9	-0.1	0.17
1210	19.6	15.0	+4.6	10.25*
1220	20.3	15.4	+4.9	6.93*
1230	17.3	16.0	+1.3	2.45*
1248	19.6	16.1	+3.5	5.43*
1256	21.0	16.8	+4.2	9.74*
1332	20.7	16.6	+4.1	4.31*
1352	19.1	16.7	+2.4	2.38*
1412	19.0	14.7	+4.3	4.14*
1422	14.1	13.9	+0.2	0.50
1512	19.0	14.6	+4.4	6.17*

[1]Temperatures after 1512 LST were not presented because the sky became cloudy. Plus signs in the difference column indicate the infested trees were warmer than the noninfested trees.

[2]Asterisk marks indicate that the given values exceed the 0.05 level value of "t" of 2.23.

Temperatures of noninfested trees were generally higher on June 28 and July 6, 7, and 17, 1973. However, the mean needle temperature of the noninfested trees was rarely 2.5°C warmer than the mean of the infested trees. On other recording days, and the remainder of the specific days, average temperatures were either the same or within 1°C of each other.

The mean temperature differences occasionally changed markedly within a specific hour or between successive recording times. For example, the mean temperature of the infested trees might be 1°C warmer than noninfested trees at a certain time, 4°C warmer 20 min later, and back to 1° warmer in another 20 min. Such changes were probably caused by some of the factors affecting individual needle temperatures.

Individual needle temperatures were affected by wind, shading, and needle location and orientation. Winds estimated to be 8-16 km/h decreased needle temperature 1.5°C; 16-32 km/h winds de-

creased the temperature 3°C. Needle temperatures were influenced by several forms of shading. Cloud cover generally decreased needle temperature. One monitored needle dropped 10°C in 5 min when a cloud obscured the sun and then regained the 10° in 75 s after re-exposure to direct sunlight. Adjacent trees, or branches of the same tree, had a similar shading effect.

Needle temperature was also influenced by the orientation of the needle toward the sun. One needle's temperature varied 2.4° with changing sun angle; its temperature was highest when the flat surface was perpendicular to the direct solar radiation.

Needle temperatures differed significantly between the east and west sides of the crowns of infested and noninfested trees. Temperatures were generally higher on the east side during the morning hours, equalized during midday, and then became higher on the west side in the afternoon (fig. 1). Differences between the east and west sides were slightly greater during the morning than in the afternoon.

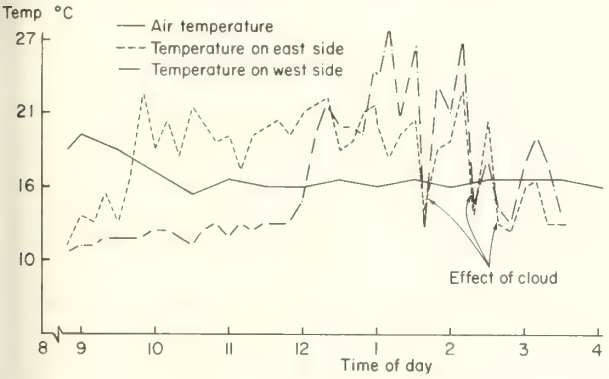


Figure 1.—Needle temperatures on east and west sides of an infested spruce on a day when significant temperature differences developed.

Weather conditions conducive to development of significant temperature differences between infested and noninfested trees were not precisely identified. Differences were greatest on days that were clear and windless during the morning and then became sparsely cloudy with estimated 8-16 km/h winds during early afternoon. Air temperatures and relative humidities at crown level ranged from 15°-17°C and 35-40%, respectively, during the midday hours. Between 6 and 10 a.m. on these days, crown level temperatures were approximately 2.8° warmer than during midday. Such days were generally proceeded by 3 or more days without precipitation. Temperatures and relative humidities on these preceding days were of similar magnitude, but cloudiness and wind varied more.

The "typical" weather conditions in the spruce-fir country partially accounted for the paucity of days with significant differences. Completely clear and windless days developed less than 15 percent of the time in June, July, and August. Frequently, either winds became strong and steady or gusty and cloud cover increased in the afternoons so that temperature differences developing during the morning hours did not continue in the afternoons. When the cloud cover built to a general overcast, needle temperatures of infested and noninfested trees became essentially identical (1° range). During these periods, needle temperatures were about 3° below the air temperature at crown level. This effect was common in the study area, and was the primary reason for so few complete days of temperature recordings with substantial differences between morning and afternoon.

The needle temperatures of the subalpine fir were higher and lower than the spruce, but not consistently either way.

Considering the temperature differences between and within infested and noninfested spruce, thermal imagery alone would not consistently detect infested spruce either before or after visual symptoms develop. Temperatures were not significantly different before visual symptoms developed and postvisual differences were sporadic. Thermal imagery would also be compounded by the development of significant east-west needle temperature differences in both infested and noninfested tree. The "typical" weather conditions in the spruce-fir forests—cloud buildup at midday and throughout the afternoon on the majority of days—also prevents temperature differences from originating.

New Growth

Branches of the infested sample trees developed new growth in the summer following the summer of beetle attack (for example, attacked in 1972, new growth in 1973). The length of the new terminal shoots ranged from 1.25 to 3 cm (averaging about 2 cm), slightly less for lateral shoots. New growth was more noticeable in the lower crown; it was sparse to nonexistent in the extreme upper crown. Other infested trees in the area also put on new growth. New growth on infested spruce trees approximately one year after attack is detrimental to possible aerial detection of infested trees because the new growth partially camouflages the desiccating needles.

Needle Fall

Needles on infested trees fell the summer of attack and the subsequent two summers. The older needles, furthest from the branch tips, fell the first summer (1972). These needles would normally drop in the fall, however, regardless of whether the tree was attacked or not, and therefore might not be influenced by the beetle attacks. Older needles also fell from September 1972 to September 1973, so that by September of the second year (1973) about 30-35% of the needles had fallen. These needles falling roughly

1 to 1.25 years after attack would also be needles normally dropping during this particular year. Since 3-4 yr old needles are drier than 1 yr old needles (Gary 1971), the additional moisture stress caused by the blue staining fungus associated with the spruce beetle probably desiccates these older needles faster than normal, and they fall sooner.

Most of the remaining 65-70% of the needles were still attached at the beginning of the third summer (June 1974) although their color varied from green to yellowish green. From June 1 to July 15, 1974, clusters of needles fell from various branch positions except for the tips or new growth of 1973. Between July 15 and July 29, 1974, strong winds accompanying one inch of rain stripped all the needles on one tree and all needles except the 1973 new growth on the other two infested trees. Only about 5 percent of the needles remained. Surrounding infested trees were similarly stripped during the same period. Just prior to the storm, needles were dry and brittle and dropped off the branch at the slightest touch. By August 22, 1974 less than 1 percent of the needles remained on the infested trees, essentially all in the lower half of the crown. The residual needles were dry and fell readily. The time of falling of these residual needles (remaining 70%) may be quite variable. If the hot dry days which accentuate the drying of needles should occur in early June, then most of the needles might be gone by mid-June. Eventually though, a storm with substantial rain and winds will strip the remaining needles from the trees and defoliation will be essentially complete 2 yrs after beetle attack.

The pattern of needle fall differs from Massey and Wygant's 1954 report which concludes that the needles on infested spruce fall after about one year. They indicate that needles may remain green until the fall of the second year, however, which would be the equivalent of the fall of 1973 in this study. A low density of beetle attacks at breast height (average of 4 per 900 cm^2 in this study versus 6.6 from Knight (1960)) and the incompleteness of the blue stain suggest that, had these factors been greater, needles may have desiccated faster and thus fallen sooner. Perhaps this observed pattern is an exception, but it seems more plausible and better documented than past reports.

Foliage Discoloration

The pattern of foliage discoloration (fading) is different in infested spruce than in infested pine because the pattern of needle dying is different. Since not all spruce needles die at the same time, or at least do not substantially desiccate at the same rate, the crown does not discolor evenly. Clusters of needles die and discolor so that the overall crown apperance is a mottled green-yellow green. The dead needles do not remain on the tree but fall during storms. The constant removal of the yellowish-green needles from the crown leaves it predominantly green but foliage is less dense and the exposed branches contribute a gray cast. This appearance predominated in the summer following attack (roughly 1 yr after attack). During the second summer, most of the remaining needles discolor so that the crown appears more uniformly yellowish green and gray. The color pattern is then more similar to faded infested pines. Eventually a storm removes the remaining needles, leaving the tree a gray skeleton.

Since aerial observers commonly look for discolored spruce as an indication of beetle infestation, their best chance of detecting such trees will be in May-June. Later observations could be worthwhile if no storms have developed. Any discolored trees found during such flights were probably attacked two years prior and will have beetles emerging about the same time as the detection flight.

Aerial detection of infested spruce is difficult because new growth on infested trees partially camouflages them and the needles do not discolor simultaneously nor remain on the tree for long periods after discoloring.

Literature Cited

Denny, C. H., E. L. Morrison, Jr., C. D. Worthman, and D. D. Lucht.
1971. Automated processing of forest imagery. *In* Proc. of 2d ARETS Symp. Univ. Ariz., Tucson. p. 111-117.

Gary, H. L.
1971. Seasonal and diurnal changes in moisture contents and water deficits of Engelmann spruce needles. Bot. Gaz. 132(4):327-332.

Heller, R. C., R. C. Aldrich, W. F. McCambridge, F. P. Weber, and S. L. Wert.
1968. The use of multispectral sensing techniques to detect ponderosa pine trees under stress from insect or pathogenic organisms. Ann. Prog. Rep., For. Remote Sensing Lab. for Nat. Resour. Prog., NASA, 45 p. [In cooperation with the Pac. Southwest For. and Range Exp. Stn.]

Knight, F. B.
1960. Measurement of Engelmann spruce beetle populations. Ecology 41:249-252.

Massey, C. L., and N. D. Wygant.
1954. Biology and control of the Engelmann spruce beetle in Colorado. U.S. Dep. Agric., Circ. 944. 35 p.

Weber, F. P.
1969. Remote sensing implications of water deficit and energy relationships for ponderosa pine attacked by bark beetles and associated disease organisms. Ph.D. Diss. Univ. Mich., Ann Arbor, 114 p.

December 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM- 332

FOREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

FEB 28 1977

Mule Deer Mortality on Interstate 80 in Wyoming: Causes, Patterns, and Recommendations

Gregory A. Goodwin and A. Lorin Ward[1]

From 1967 through 1975, 571 mule deer (*Odocoileus hemionus*) have been reported killed along a 55-mile section of Interstate 80. Mortality peaks during fall migration, and is highest at Dana Ridge where approximately 900 deer migrate across Interstate 80. The sex ratios of road-killed deer were 27 percent male and 73 percent female, compared to 23 percent male and 77 percent female in the winter population. Deer-vehicle collisions are more frequent in the eastbound lane, except at Dana Ridge where higher downhill traffic speeds result in 69 percent of the kills in the westbound lane. More fawns, predominantly female, are killed in the fall. Eight-foot deer fences can keep resident populations off highways; underpasses can funnel migrating populations under highways.

Keywords: *Odocoileus hemionus*, wildlife mortality, traffic hazards.

Wildlife mortality is increasing as the volume of traffic increases on an expanding highway network (Puglisi et al. 1974). A further understanding of the factors associated with deer highway mortality is needed for future highway planning to reduce deer-vehicle collisions and to provide additional safety for motorists.

Mortality was studied along a 55-mile stretch of Interstate 80 from Quealy Dome, 20 miles west of Laramie, to Walcott. This section of Interstate 80 parallels the Snowy Range Mountains; it presents a barrier to seasonal migration and bisects critical mule deer winter range. This situation provided a unique opportunity to study mule deer mortality associated with a major interstate highway. Our objective was to relate vegetative, physiographic, and population characteristics to the number and location of deer killed.

Interstate 80 is a divided four-lane highway with a right-of-way width varying from 400 to 600 feet. The right-of-way supports a plant community of predominately crested wheatgrass (*Agropyron cristatum*). The right-of-way fences are constructed of woven wire with either two or three strands of barbed wire at the top, with a total height of 46 inches.

[1]*The authors are, respectively, biological technician and research wildlife biologist, Rocky Mountain Forest and Range Experiment Station; research reported here was conducted at the Station's Research Work Unit at Laramie, in cooperation with the University of Wyoming. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Construction of the highway began in 1967, and was opened to traffic on October 3, 1970. The average daily traffic reported by the Wyoming State Highway Department from 1972 to 1975 was 4,231 vehicles. The heaviest traffic occurred in August (7,584 cars) and the lowest in January (2,012 cars).

The areas surrounding Interstate 80 are sparsely populated and used primarily for livestock grazing. The average elevation is 7,393 feet and the topography is characteristic of foothills including rolling plains, ridges, and pronounced escarpments. The eastern half of the study area is predominately shortgrass prairie; the western half is comprised of extensive stands of big sagebrush (*Artemisia tridentata*). Isolated areas throughout the study area are dominated by true mountainmahogany (*Cercocarpus montanus*), antelope bitterbrush (*Purshia tridentata*), and black greasewood (*Sarcobatus vermiculatus*) which provide important mule deer habitat.

Methods

For the period January 1967 through March 1973, mule deer mortality data consisting of date and approximate locations were obtained from warden reports supplied by the Wyoming Game and Fish Department. Data from April 1973 through January 1976, including sex, exact location, lane (eastbound or westbound), condition, and age were recorded during daily observation trips during migration periods and biweekly trips during the remainder of the year.

Age was determined in the laboratory by examination of incisors for the number of cementum annuli (Low and Cowan 1963) following the procedure described by Crowe (1972).

A 35-mm time-lapse camera (Diem et al. 1973) was used to monitor deer crossings on a 3-mile section of Interstate 80 at Dana Ridge. In the fall of 1974 and 1975, track counts, when snow conditions permitted, were made to estimate the number and locations of crossings at Dana Ridge.

Results and Discussion

Distribution of Deer Mortality

Mule deer center their activities in five areas along Interstate 80: Cooper Cove, Arlington, Wagonhound Creek, Medicine Bow River, and Dana Ridge. The number of deer-vehicle collisions is related to the population size and the physiographic features of each area.

The Cooper Cove area supports an increasing winter population. In 1975, 113 deer were known to have crossed Interstate 80 during the migration. Twenty-two mule deer have been reported killed between April 1973 and December 1975 along this 5.5-mile section of Interstate 80, for a yearly average of 1.3 deer per mile. Forty-five percent of the kills occurred along a 1-mile section of highway that passes through the center of the winter range, where the daily movement of deer results in many crossings. Another 36 percent of the kills occurred along a 1-mile section near Cooper Creek, and were associated with movement along the stream drainage which provides cover and forage.

Resident and migrating populations contribute to vehicle collisions at Arlington. Approximately 100 migrating deer do not cross Interstate 80 during movement to the winter range adjacent to the highway, but they do occasionally cross the highway while occupying this range. The small resident population of 15 to 25 deer creates a potential for highway mortality throughout the year. Forty-eight deer have been reported killed since 1973 along 5.4 miles of Interstate 80, resulting in a yearly average of 2.9 per mile. Most collisions (46 percent) occurred within 0.5 mile of Rock Creek. This drainage supports a dense deciduous forest that borders both sides of Interstate 80. Twenty-five percent of the kills occurred near Threemile Creek, a small stream drainage crossed by Interstate 80.

Wagonhound Creek is a crossing point for up to 200 deer migrating north to a winter range. The number of deer killed, which has increased each year since 1973 due to an increasing population, totals 43 along 4.3 miles of Interstate 80, for an average of 3.3 per mile per year. Deer-vehicle collisions are concentrated near Wagonhound Creek, where topography and vegetation may influence deer movement adjacent to and across Interstate 80.

Resident and migrating deer contribute to mortality in the Medicine Bow River area. Thirty-seven deer have been reported killed along 5.5 miles of Interstate 80, averaging 2.2 per mile per year. There are two areas of high mortality. The first is adjacent to the river, reflecting mortality within the resident population of approximately 40 deer. The remaining mortality occurs within a small migrating population south of the river.

The Dana Ridge area is the crossing point for approximately 900 mule deer during their annual migrations. In the spring, deer migrate from late April through early June, and in the fall, from late November through early January. Few deer spend the winter or summer at Dana Ridge.

No deer were recorded by the 35-mm time-lapse camera from October 1973 through June 1974, indicating the majority of deer cross the highway at night or during poor light conditions at dawn and dusk. The following two winters, track counts in the snow were made to determine major crossing points.

Dana Ridge has the highest mortality of any area along Interstate 80 due to the large number of deer that cross. Seventy deer have been reported killed along 7.9 miles of the highway, for a yearly average of 2.9 deer per mile. Forty percent of all the crossings and 47 percent of all deer-vehicle collisions occurred along a 1-mile section of Interstate 80, resulting in an average of 342 crossings and 19.7 deer killed per mile. This section of Interstate 80 is characterized by 30-foot cuts through a series of rocky, sparsely vegetated ridges that run perpendicular to the highway.

Near the heavy crossing area at Dana Ridge, the right-of-way fence was relocated and run perpendicular to the underpass to guide deer into an existing underpass structure. During the 1974-75 and 1975-76 migrations, 39 tracks were counted in the underpass. This represents only a small portion of the deer that cross Interstate 80, but does suggest that deer will use the underpass.

Deer-vehicle collisions occurred slightly more often in the eastbound lane throughout the year except at Dana Ridge. The eastbound lane is adjacent to the summer range in all areas, and is the first traffic encountered by fawns.

It is difficult to analyze the factors associated with mortality between lanes except for Dana Ridge, where Interstate 80 goes down a steep slope for 3 miles. Of the 70 animals killed here since 1973, 69 percent were killed in the westbound land going down the ridge. To determine if the downhill traffic speeds were higher and thus contributing to the differential mortality between lanes, traffic speeds were sampled on two days during peak migration. Truck speeds averaged 70.3 mph going downhill and 44.4 mph going up. Car speeds averaged 68.7 mph downhill and 65.8 mph uphill. The higher truck speeds down the ridge contribute to the increased mortality in the westbound lane and to the Dana Ridge area. Reducing the speed limit to 55 mph on March 3, 1974 has not measurably reduced the number of deer-vehicle collisions.

Sex and Seasonal Variation

Since the beginning of construction in 1967, 571 mule deer have been reported killed on the 55-mile study section of Interstate 80. Sex, date, and location data were collected for 219 deer killed since April 1973.

Mortality was lowest in late winter and late summer, and highest during the fall migration (fig. 1). Male and female mortalities were similar throughout most of the year except in spring, when male mortality was low and female mortality high (fig. 1). The higher male mortality in the fall is probably associated with the breeding season. The overall sex ratios of road-killed deer—27 percent male and 73 percent female—were similar to the population structure of deer observed on the winter range—23 percent male and 77 percent female. Male mortality was highest (34 percent) at Wagonhound Creek, reflecting the lowered exploitation of bucks in a population that received limited hunting pressure.

Deer are observed in the right-of-way most frequently in spring, feeding on "greening up" crested wheatgrass, the only species planted in the right-of-way. Early growth of crested wheatgrass is characterized by abundant leafiness, a high percentage of crude protein, and a high mineral content (Rauzi 1975). Mule deer diets are comprised of up to 19 percent grass in the spring (Goodwin 1975). These factors contribute to spring mortality by attracting deer into the right-of-way.

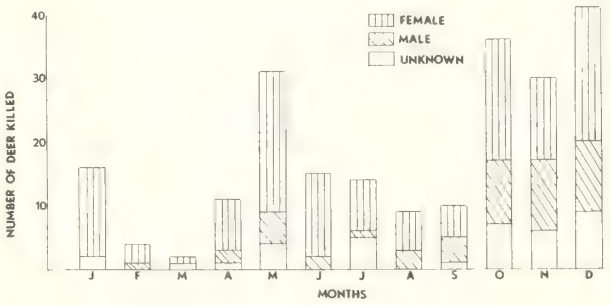


Figure 1.—Male and female deer mortality on Interstate 80 from April 1973 through December 1975.

Age Distribution

The age distribution of mule deer killed on Interstate 80 is characterized in the following tabulation by percentage of animals in the various age classes:

Age class	Males	Females
	percentage in age class	
0 & 1	43	40
2	20	19
3	20	19
4	7	9
5	7	6
6	2	2
7	—	2
8	—	1
9	—	2
10	—	1

Limited data suggest the age structure of the local population is similar.

There is considerable seasonal variation in mortality by age class. During the fall migration (October through January), 30 percent of the deer killed were fawns; during the spring migration (April through June), only 7 percent were fawns. The disproportionate losses between seasons could be attributed to winter losses of fawns. Robinette et al. (1957) reported that the winter loss of fawns is two to three times that of adult deer.

Forty-three fawns have been killed on Interstate 80 since 1973, and only 13 (30 percent) were males. Although the small sample size limits a good evaluation, these data would indicate that male fawns are either less vulnerable to vehicle collisions, or since the greatest fawn mortality occurs in the fall there is greater mortality of male fawns during the summer. Robinette et al. (1957) noted that early postnatal mortality during the first three months may take a higher proportion of male fawns.

Management Implications

Current efforts to reduce deer-vehicle collisions have centered around 8-foot high deer fencing along highway rights-of-way. These fences force deer to use underpass structures to cross highways. Deer fences have been successful in funneling deer into a 10-foot by 10-foot underpass, approximately 100 feet long, under Interstate 70 near Vail, Colorado (Gilbert et al. 1971).

Efforts have also been made to develop a better method of warning motorists of potential deer crossing areas. A lighted, animated deer-crossing sign tested on a State highway in Colorado had little effect on traffic speed or accidents, however (Pojar et al. 1975).

We suggest that deer fences be constructed where large numbers of deer are struck by vehicles. If deer are migrating across the highway, an underpass structure should be located where deer can be funneled into it. In areas where the highway parallels or crosses traditional winter or summer ranges, it may not be necessary to provide a means for deer to cross the highway, but rather, a means to keep them off the highway.

Future highway construction should take into account the characteristics of deer crossing areas. Preconstruction data should be obtained on migration routes, winter and summer ranges that will be crossed, and population densities. Then necessary steps can be taken to prevent accidental deer mortality and auto damage. Cooperation between highway designers and wildlife managers can effectively reduce the number of deer-vehicle collisions.

Literature Cited

Crowe, D. M.
1972. The presence of annuli in bobcat tooth cementum layers. J. Wildl. Manage. 36(4):1330-1332.

Diem, K. L., A. L. Ward, and J. J. Cupal.
1973. Cameras as remote sensors of animal activities. XI Int. Congr. of Game Biol. Proc., Stockholm, Sweden. 9 p.

Gilbert, D. F., D. F. Reed, and T. M. Pojar.
1971. Migratory deer and Interstate 70 in western Colorado. *In* Proc. 51st West. Assoc. of State Game and Fish Comm., p. 436-446.

Goodwin, G. A.
1975. Seasonal food habits of mule deer in southeastern Wyoming. USDA For. Serv. Res. Note RM-287, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Low, W. A., and I. M. Cowan.
1963. Age determination of deer by annular structure of dental cementum. J. Wildl. Manage. 27(3):466-471.

Pojar, T. M., R. A. Prosence, D. F. Reed, and T. N. Woodward.
1975. Effectiveness of a lighted, animated, deer crossing sign. J. Wildl. Manage. 39(1):87-91.

Puglisi, M. J., J. S. Lindzey, and E. D. Bellis.
1974. Factors associated with highway mortality of white-tailed deer. J. Wildl. Manage. 38(4):799-807.

Rauzi, F.
1975. Seasonal yield and chemical composition of crested wheatgrass in southeastern Wyoming. J. Range Manage. 28(3):219-221.

Robinette, W. L., J. S. Gashwiler, J. B. Low, and D. A. Jones.
1957. Differential mortality by sex and age among mule deer. J. Wildl. Manage. 21(1):1-16.

December 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-333

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

FEB 25 1977

Induced Single-Flush Synchronous Growth of Shrub Live Oak[1]

Edwin A. Davis[2]

When shrub live oak is grown under favorable greenhouse conditions, the plants generally grow nonsynchronously after a common flush of growth in the spring. The results of this study indicate that it is possible to induce a single flush of synchronous growth from nonsynchronously growing plants by clipping terminal shoots, since release of lateral buds and subsequent regrowth was not affected by the stage of shoot development at time of clipping. The technique should be useful in studies to determine the effect of stage of shoot development on the effectiveness of foliage-applied herbicides.

Keywords: *Quercus turbinella,* foliage-applied herbicides, synchronous growth.

Under greenhouse conditions shrub live oak (*Quercus turbinella* Greene) generally grows in a rhythmic pattern in which a flush of growth is followed by a period of temporary dormancy. The cycle continues as long as the plant is provided with the necessary conditions for growth. This type of growth is sometimes referred to as episodic (Romberger 1963). Shoots on different plants or on the same plant grow nonsynchronously, that is, they do not necessarily grow at the same time.

[1]*Same information published in GEOBIOS 3:181-184, 1976.*

[2]*Plant physiologist at the Station's Forest Hydrology Laboratory, Tempe, in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Unpruned greenhouse seedlings of shrub live oak develop into a relatively unbranched plant form characteristic of plants with strong apical dominance. This may result from the production of relatively large amounts of auxin in the apex, and the balance and interactions of auxin, ethylene, and cytokinin (Leopold 1955, Galston and Davies 1970, Kozlowski 1971). If shoots are clipped, the top lateral bud or buds are released, and shoots from these buds grow rapidly. This is known as compensatory growth of lateral buds (Jacobs and Bullwinkel 1953). The inhibition of lateral buds before clipping is an example of correlated inhibition (Romberger 1963).

Since the growth pattern of shrub live oak is characterized by alternate periods of temporary dormancy and growth, it is possible that the stage of shoot development at time of clipping has an effect on the release of lateral buds and subsequent growth

of lateral shoots. The question investigated in this study is whether clipping temporarily dormant shoots is equivalent to clipping actively growing shoots with respect to the release of lateral buds. If their release is not affected by stage of development of the clipped terminal, it could mean that temporarily dormant shoots have no greater inhibiting effect on lateral buds than shoots undergoing a flush of growth. From a practical standpoint it should then be possible to induce a single flush of synchronous growth from nonsynchronously growing plants. Such a technique would be useful in studies to determine the effect of stage of shoot development on the effectiveness of foliage applications of herbicides on shrub live oak, or in other studies where synchronous growth is desired. The response of shrub live oak to terminal clipping of dormant or actively growing shoots may also be of interest to wildlife biologists concerned with the response of shrubs to browsing.

Methods

Experiment 1

In the first of two experiments, 3-year-old potted shrub live oak plants were cut back to 6 inches and allowed to regrow. When the plants were about 16 inches tall, shoots were selected that were either temporarily dormant or actively growing. Shoots in the temporarily dormant condition had mature hardened leaves and a temporarily dormant terminal bud. Actively growing shoots were in the late stem elongation stage, and were elongating rapidly (fig. 1).

The plants had multiple shoots, but only one shoot was chosen for study on each plant. There were 8 shoots in the temporarily dormant stage and 11 shoots in the actively growing stage. The dormant shoots were clipped below the third hardened leaf

Figure 1.—Two stages of shoot growth of shrub live oak: (Left) temporarily dormant shoots, and (right) actively growing shoots in the late stem elongation stage.

from the top. The actively growing shoots were clipped immediately below the third hardened leaf of the previous flush. The growth of lateral shoots following clipping was measured as increase in shoot length. After the regrowth shoots completed a flush of growth, they were harvested and weighed fresh; only one lateral shoot developed from each clipped shoot.

Experiment 2

The second experiment was conducted with 5-year-old potted plants that had been pruned many times. Actively growing shoots in the late stem elongation stage and temporarily dormant shoots were selected from a large group of plants. Each stage of shoot growth was represented by 28 shoots. In most cases a plant contained only one experimental shoot, but in a few cases it was necessary to use two shoots per plant. The clipping procedure was the same as in the first experiment. About half of the clipped stems developed just one lateral regrowth shoot; the others developed two to four laterals, the top one being the lead shoot and the lower ones growing progressively less. When more than one lateral shoot developed on a clipped shoot, their combined lengths and final fresh weights were used as measures of regrowth.

Results and Discussion

Lateral shoot growth of shrub live oak was the same after either temporarily dormant or actively growing shoots were clipped, measured either as increase in length (fig. 2) or as final fresh weight of regrowth shoots:

	Experiment 1[3]	Experiment 2[3]
	(*g*)	(*g*)
Temporarily dormant	1.24 ± 0.43	2.15 ± 0.49
Actively growing	1.17 ± .37	2.47 ± .49

The regrowth shoots were harvested and weighed after they completed a flush of growth. The stage of

[3] *The ± in tabulation indicates mean ± $t_{.05}$ × standard error.*

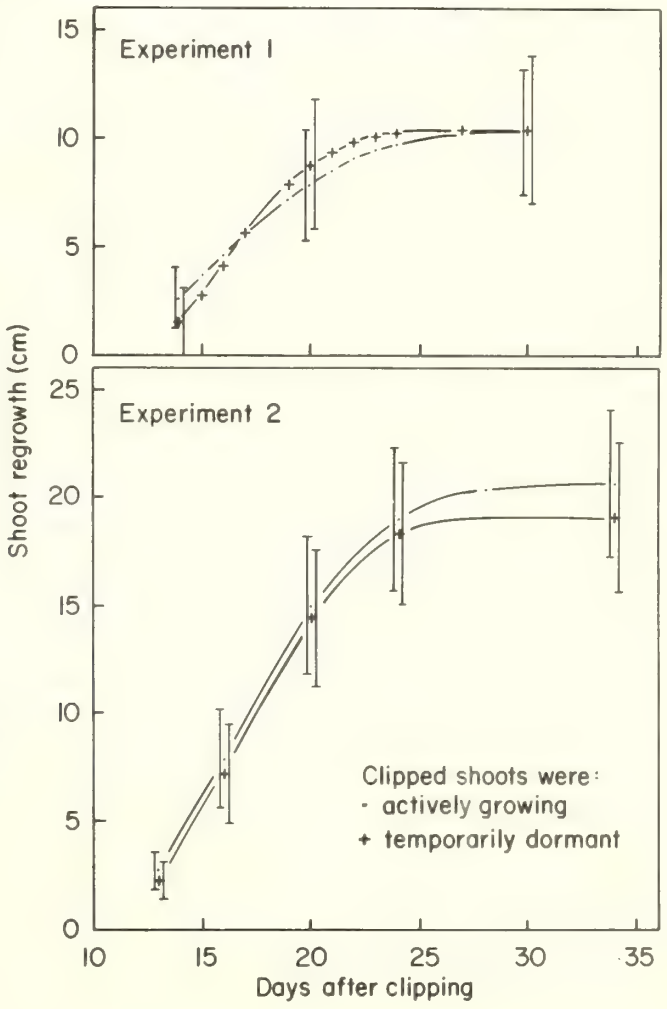


Figure 2.—Shoot regrowth of shrub live oak after terminal clipping of temporarily dormant and actively growing shoots. The vertical lines represent the 95% confidence limits of the population means.

shoot development at the time of clipping did not significantly affect regrowth from released lateral buds. This suggests, for shrub live oak, that an actively growing shoot has no greater inhibiting effect on lateral buds than a temporarily dormant shoot. The results also indicate that the upward mobilization of nutrients and perhaps growth substances to the new flush of growth did not stimulate lateral shoots to a level above that caused by clipping temporarily dormant shoots, which were presumably transporting foodstuffs downward.

Elements in common to both types of shoots before they were clipped were the mature hardened leaves above and below the point of excision. It is possible that these mature leaves exerted the major influence on the lateral buds (Leopold 1964, Wareing and Phillips 1970).

When shrub live oak is grown under favorable greenhouse conditions, the plants generally grow nonsynchronously after a common flush of growth in the spring. The results of this study indicate that it is possible to induce a single flush of synchronous growth from nonsynchronously growing plants by clipping terminal shoots, since release of lateral buds and subsequent regrowth was not affected by the stage of shoot development at time of clipping.

Literature Cited

Galston, A. W., and P. J. Davies.
1970. Control mechanisms in plant development. 184 p. Prentice-Hall Inc., Englewood Cliffs, N.J.

Jacobs, W. P., and B. Bullwinkel.
1953. Compensatory growth in *Coleus* shoots. Am. J. Bot. 40:385-392.

Kozlowski, T. T.
1971. Growth and development of trees. Vol. 1. Seed germination, ontogeny, and shoot growth. 443 p. Acad. Press, N.Y.

Leopold, A. C.
1955. Auxins and plant growth. 354 p. Univ. Calif. Press, Berkeley and Los Angeles.

Leopold, A. C.
1964. Plant growth and development. 466 p. McGraw-Hill Book Co., N.Y.

Romberger, J. A.
1963. Meristems, growth, and development in woody plants. U.S. Dep. Agric., Tech. Bull. 1293, 214 p.

Wareing, P. F., and I. D. J. Phillips.
1970. The control of growth and differentiation in plants. 303 p. Pergamon Press, N.Y.

February 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-334

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Size and Moisture Content of Pulp Chips From Living and Dead Engelmann Spruce and Subalpine Fir

JUN 7 1977
SCI., TECH. & AGR. DIV.

Donald C. Markstrom, Harold E. Worth
and
Thomas Garbutt[1]

Sieve analysis indicates that the average size of pulp chips produced by an inwoods chipping system from live and dead timber were nearly the same — 0.53 vs. 0.49 inch. The percentage of fines passing the 3/16 inch-diameter screen was 1.7% higher for the dead than for the living timber. The average moisture content of the chips decreased from 82% for living Engelmann spruce and 107% for living subalpine fir to an average of 42% based on ovendry weight for the dead wood of both species.

Keywords: Pulpchips, residue utilization, *Picea engelmannii, Abies lasiocarpa.*

It usually takes many years for a dead tree to decompose entirely and return to the soil. In the early stages there is a high proportion of wood that is as usable as if the tree had been freshly harvested. As time goes on, however, this proportion decreases until the tree has no practical product value. Since the dead timber in a given stand often covers this entire range of deterioration, a practical question for pulp producers is: How much of this dead material can be successfully used in pulp? If pulp can be satisfactorily made from sound dead wood, a sizable fraction of the forest resource now wasted can be utilized.

[1]*The authors are, respectively, Wood Technologist and Principal Wood Technologist, at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, headquartered at Fort Collins, Colorado, in cooperation with Colorado State University; and Technical Director, Snowflake Pulp Mill, Southwest Forest Industries, Inc., Snowflake, Arizona.*

For pulping purposes, three characteristics of dead wood are of major importance — moisture content, amount of decay, and mechanical properties. Mechanical properties are in part affected by moisture content and decay. The size of chips produced is also important in pulping and can be affected by the three characteristics. The purpose of this research was to determine how chips produced from dead wood compare with those produced from freshly cut timber.

This Note describes and compares the size and moisture content of pulp chips from living and dead Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). The results were obtained as part of a larger study to evaluate an inwoods debarker-chipper system conducted cooperatively between Southwest Forest Industries, Inc. and the USDA Forest Service on the Dolores Ranger District of the San Juan National Forest during the fall of 1973 (fig. 1) (Sampson et al. 1974).

Figure 1.—Inwoods debarker-chipper system at field test site, Dolores Ranger District, San Juan National Forest.

The need to measure chip size and moisture content resulted from a decision to include a high proportion of dead wood in the material to be chipped in the Colorado phase of the study. Spruce-fir stands in this area contain large volumes of dead and down timber. Inwoods chipping presented a possible opportunity for harvesting such material economically.

Chips produced from the mixture of live and dead timber at this site were subsequently pulped by a sulfate process at the Snowflake, Arizona pulp and paper mill. Dead timber, including both standing and down trees, with an estimated 50% or more sound wood were brought in and chipped with the live thinnings. Some decay in these trees had reached the advanced stage where the wood was soft and crumbly. Bark retained on the dead logs after skidding and before debarking was variable, ranging from 0% to nearly 100%. The volume of dead wood chips salvaged was 62% of the total.

Pulp mill personnel judged that the pulp quality and yield from this particular mixture of chips were satisfactory when the mixture was blended with the regular supply of chips. However, since other timber sale areas would likely have a different mix of live and dead timber, this study was designed to evaluate the effects of tree species, living or dead condition, and tree size on chip size and moisture content.

The importance of chip size and moisture content in pulping has been documented (Chelsey and Robertson 1944, de Montmorency 1969, Hatton and Keays 1971, and Nolan 1959). It is generally recognized that a higher proportion of finer particles may be produced from both dry and decayed timber. Decay was not measured independently in this study; however, the effects of decay alone on pulp yield and quality is discussed by Hale (1969).

Sampling

Chips from 235 individual logs, representing a total of 31 different 10-unit van loads, were sampled. An initial sample log was selected at random from logs 1 through 9 for each van load and, thereafter, every 16th log was sampled. As each sample log was fed to the debarker-chipper, it was visually characterized as living or dead and identified as spruce or fir. To avoid production delays, chips were sampled with a wire screen "butterfly" net passed through the stream of chips from each sample log as they were blown from the spout of the debarker-chipper into the chip van. The net was of conical shape with a 12-inch-diameter opening and a depth of 20 inches; the screen mesh had square openings of approximately 0.15 inch. Each chip sample was divided between two polyethylene bags, labeled, and weighed. Chips for the moisture content analysis were placed in one bag and those for the sieve analysis in the other.

Analysis Methods

Chip Size

The 235 individual netted samples collected in the field were combined into 24 larger samples, which provided 3 replications for each of the following 8 combinations of variables:

Species	Condition	Log Diameter *Inches*
Engelmann spruce	living	≥ 11
		< 11
	dead	≥ 11
		< 11
Subalpine fir	living	≥ 11
		< 11
	dead	≥ 11
		< 11

Combining samples was necessary to: (1) provide adequate sample size for a sieve analysis, and (2) be certain that each sample reflected chipper knife conditions over the duration of at least one period between sharpenings. (The effect of properly ground knives on chipper performance has been reported by Lamarche 1969.) The air-dry weights of the 24 samples ranged from 260 to 985 grams. In the sieve analysis, each sample was shaken for 3 minutes in a Williams classifier, using a set of five sieves with round openings of 1-1/8, 7/8, 5/8, 3/8, and 3/16 inches. Fine particles passing through the 3/16-inch sieve were caught in a pan. Each fraction was weighted in tared containers to the nearest 0.1 gram. The sieving procedure was exactly the same as that used regularly by the pulpmill, thus enabling direct comparison of experimental data with production data.

The percent of chips retained on each sieve and in the pan, and the average sieve size of the chips were calculated. Average sieve size of chips was calculated as follows:

$$\overline{X} = \frac{\Sigma W_i x_i}{100}$$

where:

$\overline{X}$ = average sieve size of chips or particles — inches

W_i = weight of chips or particles collected on the ith sieve as a percent of total sample weight

X_i = size of opening in ith sieve — inches

Moisture Content

The 235 moisture samples were ovendried at 103°C for 24 hours in a forced-air oven. Several of the samples were weighed after both 18 and 24 hours to be certain that the 24-hour period was adequate. Moisture content was calculated on an oven-dry basis.

Results

Sieve Analysis

The proportions of chips retained on the various sieves and the average sieve size of the chips for each combination of variables are shown in table 1. Analysis of variance of the data in a 2 by 2 by 2 factorial experiment indicated the following effects.

Table 1.—Percent of chips retained by each sieve and mean sieve size of chips for each combination of species and living or dead condition[1]

Sieve opening diameter-(inches)	Engelmann spruce		Subalpine fir	
	Living	Dead	Living	Dead
	Percent			
1-1/8	6.6	7.4	6.0	8.2
7/8	12.0	7.6	9.0	8.8
5/8	32.8	23.0	28.0	21.8
3/8	37.9	40.3	42.4	41.4
3/16	9.9	18.5	13.4	17.5
Pan	0.8	3.2	1.2	2.3
Mean sieve size of chips-inches	0.55	0.48	0.51	0.49

[1] *The percent values are the means for six observations.*

Average sieve size of chips did not vary significantly with either species or log diameter alone. Average sieve size for all Engelmann spruce was 0.51 inch and subalpine fir, 0.50 inch. The average chip size for logs with a diameter ≥ 11 inches was 0.50 inch and for logs with a diameter < 11 inches was 0.51 inch.

Chips from living trees were slightly larger than those from dead trees — 0.53 inch versus 0.49 inch. Table 1 shows that the proportion of fines retained in the pan was also lower for living timber than for dead. However, this slight reduction in chip size of 0.04 inch and increase in fines of 1.7% would not render such furnish at all unsuitable for the sulfate pulping process. The slightly smaller size of chips from dead trees probably resulted from the greater brittleness of dry wood.

Moisture Content

Analysis of variance of the moisture content data in a 2 by 2 by 2 factorial experiment indicated the following (table 2): Average chip moisture content did not vary significantly with either species or log diameter alone. The average moisture content (weight of moisture expressed as a percent of the ovendry weight of the wood) for all Engelmann spruce chips was 61% and for subalpine fir, 77%. The average moisture content for logs with diameter ≥ 11 inches was 69% and for logs with diameter < 11 inches was 68%. Chips from living trees, as would be expected, had a significantly higher moisture content than those from the dead trees. The greater difference in moisture content between the two species in the living condition as compared to dead is probably related to the physiology of the living trees. When dead trees of different species lose moisture, they tend to equalize over time, as is the case with wood products in use.

Table 2.—Moisture content[1] of pulpchips for combinations of species, living or dead condition, and log diameter

Log diameter (inches)	Engelmann spruce		Subalpine fir	
	living	dead	living	dead
	Percent			
≥ 11	76	39	110	51
< 11	88	39	105	41
Aver.	82	39	107	46

[1] *Expressed as a percent of ovendry weight of chips.*

The effect of the interaction between log diameter and species on moisture content was also statistically significant but of little practical importance. Average moisture content increased with diameter from 58% to 64% for Engelmann spruce but decreased from 81% to 73% for subalpine fir.

Conclusions

A major conclusion is that the size of pulp chips produced from various proportions of living and dead Engelmann spruce and subalpine fir would not vary enough to be of practical importance for pulping. In the range from all live to all dead wood, average sieve size decreased 0.04 inch and the percentage of fines increased 1.7%. The practice at the Snowflake mill is to carefully examine the percentage of oversize chips (> 1-1/8 inches) and fines (< 3/16 inch). An increase in fines will lower pulp yield, while an increase in oversized chips, depending on geometry, can influence the percent of screenable rejects and the pulp yield and quality. The geometry of the oversize chips must be considered; otherwise long ribbons of perfectly good chips could be rejected as oversized (Hatton and Keays 1971).

A second major conclusion is that the moisture content of chips, depending upon the various proportions of living and dead Engelmann spruce and subalpine fir, could affect pulping, chipping, and hauling costs. The average moisture content of the chips decreased from an average of 82% for living Engelmann spruce and 107% for living subalpine fir to 42% for dead wood of both species. However, the moisture content of the chips, particularly from dead timber, could be expected to vary with local and seasonal weather.

Literature Cited

Chesley, K. G., and N. F. Robertson.
1944. The effect of small chip sizes in sulphate pulping. Tech. Assoc. Pulp Paper Ind. Tech. Assoc. Pap. Serv. 27:379-383.

Hale, J. D.
1969. Structural and physical properties of pulpwood. *In* Pulp and pap. manuf.: The pulping of wood. Vol. 1. Ronald G. MacDonald and John N. Franklin, eds. McGraw-Hill Book Co., N.Y., 769 p.

Hatton, J. V., and J. L. Keays.
1971. Effect of raw materials and process variables on close control of the kraft pulping process. Dep. Environ., Can. For. Serv., Vancouver, B.C. 16 p.

Lamarche, F. E.
1969. Preparation of pulpwood. *In* Pulp and pap. manuf.: The pulping of wood. Vol. 1. Ronald G. MacDonald and John N. Franklin, eds., McGraw-Hill Book Co., N.Y., 769 p.

Montmorency, W. H. de.
1969. Wood chips for the chemical and mechanical pulp processes. Pulp Pap. Mag. Can. 85-86. WS Index 2505 ODC 363:7.

Nolan, W. J.
1959. The importance of chip moisture in kraft pulping. TAPPI 42:320-327.

Sampson, George R., Harold E. Worth, and Dennis M. Donnelly.
1974. Demonstration test of inwoods pulp chip production in the four corners region. USDA For. Serv. Res. Pap. RM-125, 18 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

ary 1977

USDA FOREST SERVICE
RESEARCH NOTE RM- 335

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Early Field Survival of Bare-Root, Container-Grown, and Potted Ponderosa Pine Seedlings in South-Central Nebraska

John A. Sprackling[1]

CLEMSON UNIVERSITY LIBRARY
JUN 7 1977
SCI. TECH. & AGR. DEV.

Two trials in south-central Nebraska indicate no significant differences in survival of bare-root versus container-grown or potted seedlings. Container-grown seedlings grew faster than bare-root stock after establishment.

Keywords: Container-grown seedlings, shelterbelts, *Pinus ponderosa*.

Among the conifers, ponderosa pine (*Pinus ponderosa* var. *scopulorum*) is second only to eastern redcedar (*Juniperus virginiana* L.) in numbers planted in Nebraska. Until recently, virtually all seedlings distributed in the Nebraska Clarke-McNary program were nursery-grown, bare-root (2+0 or 2+1) stock. However, initial survival has been erratic. Thus potted and container-grown seedlings, though initially more expensive, have been planted in recent attempts to improve survival. Comparisons have indicated that container-grown stock survived better than bare-root stock in the Northern Plains (Hite 1974, Tinus 1976). This Note reports trials of bare-root versus container-grown and bare-root versus potted ponderosa pine planting stock at one site in south-central Nebraska.

[1] *Forestry research technician, located at the Station's Research Work Unit at Lincoln, in cooperation with University of Nebraska; Station's central headquarters is maintained at Ft. Collins, in cooperation with Colorado State University.*

Methods

The study site is 3 miles east of Hastings, Nebraska on open, level land of uniform silty-clay-loam soil. Mean annual precipitation is 26.6 inches. In the year prior to the first trial (1974), annual precipitation was 8.32 inches below normal. During the first year (1975), precipitation was normal or better during April through July, but was deficient thereafter. Every month in 1976, except April, had below-normal precipitation.

Two field tests were made. In April 1975, 58 bare-root, 2+0 ponderosa pine seedlings of Niobrara, Nebraska seed source grown at Bessey Nursery, and 58 container-grown (Spencer-Lemaire) 9-month-old ponderosa pine seedlings of Rosebud, South Dakota seed source grown in a greenhouse at Bottineau, North Dakota were alternately planted by machine 6 feet apart in a single row. Trees were removed from the container just before planting. Survival and height data were recorded in spring and fall 1976.

In May 1976, 26 bare-root, 2+0 ponderosa pine seedlings were alternately planted by hand 5 feet apart with 26 potted, 2+1 ponderosa pine seedlings.[2] Both bare-root and potted trees were of San Isabel National Forest, Colorado seed source, and were grown at the Colorado State Forest Service nursery at Ft. Collins, Colorado. Tarpaper pots were removed just before planting. Survival and height were measured after the first growing season, in fall 1976. Both plots were maintained by annual application of Simazine 80W (4 lbs /acre) and periodic mowing to reduce grass competition. Survival data were subjected to a chi-square test to determine whether differences were significant.

Results and Discussion

Survival was high in both plantings despite below-normal precipitation during the growing seasons. After a full year, 98% of the container-grown seedlings were alive compared to 95% of the bare-root seedlings. Heights of bare-root stock averaged 0.67 foot and container-grown stock 0.43 foot after one growing season. During the second season there was no mortality, and the container stock outgrew the bare-root stock, thus narrowing the difference in average height — 0.82 foot for container-grown seedlings; 0.99 foot for bare-root.

In the second test after one growing season, all of the potted seedlings and 88% of the bare-root seedlings were alive. First-year average heights were identical — 0.63 foot.

In summary, the differences in survival of bare-root versus container-grown and bare-root versus potted seedling planted in south-central Nebraska were not significant at the 0.05 level. Container-grown seedlings grew faster than bare-root stock during the second season, however.

[2]*Bare-root seedlings were lifted at age 2, transplanted in soil in tarpaper pots, and grown in a shadehouse for a year.*

Literature Cited

Hite, Wayne A.
1974. Container field performance in the Rockies and Plains. p. 306-309. *In* Proceedings of the North American Containerized Forest Tree Seedling Symposium, Great Plains Agric. Counc. Publ. No. 68.

Tinus, Richard W.
1976. Greenhouse container nurseries for better trees. p. 137-140. *In* Proceedings of Symposium on Shelterbelts on the Great Plains, Great Plains Agric. Counc. Publ. No. 78.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.

February 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-336

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of a Prescribed Fire in an Arizona Ponderosa Pine Forest

Peter F. Ffolliott, Warren P. Clary,
and Frederic R. Larson[1]

CLEMSON UNIVERSITY LIBRARY
JUN 7 1977
SC TECH

A prescribed fire in 1964 consumed nearly three-fourths of the total forest floor. Eleven years after the fire, compaction of initial needle drop plus normal annual needle fall have created a forest floor depth two-thirds that of the prefire level. More ponderosa pine seedlings started on the burned areas than under adjacent unburned stands and herbage production increased, but not to levels adequate for grazing.

Keywords: Prescribed fire, litter production.

Introduction

In October 1964, a fire was set to burn approximately three-fourths of the forest floor depth in a ponderosa pine forest near Flagstaff, Arizona. Generally, this objective was accomplished (Davis, Ffolliott, and Clary 1968). Other effects of the fire included thinning of the forest overstory from below, increased seedling establishment, and a temporary reduction of fire hazard. Forage and browse remained practically unchanged.

The investigation described herein was conducted to assess the effects of this prescribed fire 11 years after burning on those characteristics originally modified by the burn.

[1]*Ffolliott is Associate Professor, School of Renewable Natural Resources, Univ. of Ariz., Tucson; Clary is Principal Range Scientist at Southern Forest Experiment Station, Pineville, La.; Larson is Silviculturist at Rocky Mountain Forest and Range Experiment Station, Flagstaff, in cooperation with Northern Ariz. Univ.; Station's central headquarters is maintained at Fort Collins, in cooperation with Colo. State Univ.*

Methods

The fire prescribed was intended to consume three-fourths of the depth of a 1.5- to 3-inch layer of forest floor on two ¼-acre areas (A and B). To this end, a surface fire with an average flame height of 2 feet was attained (fig. 1). The estimated fire intensities were 48 BTU's per second per foot on area A, and 90 BTU's per second per foot on area B. The specific conditions selected for achieving the prescribed fire have been summarized in an earlier report (Davis et al. 1968).

The density of the prefire even-aged forest overstory on area A was 170 square feet of basal area per acre, with an average tree diameter of 6 to 8 inches d.b.h. On area B, the even-aged overstory was 305 square feet of basal area per acre, with an average tree diameter of 14 to 16 inches d.b.h. On each area, 16 sample points were systematically spaced 25 by 25 feet. Data taken before burning, within 2 years after burning, and 11 years after burning include:

Figure 1.—Average flame height of the prescribed fire was approximately 2 feet.

Forest floor depth: forest floor surface to mineral soil.
Timber density: estimated by point sampling with a basal area factor (BAF) gage of 25 at each sample point.
Seedling establishment: mil-acre plots stocked, 16 on and 16 adjacent to each burned area.
Herbage production: weight of grasses, forbs, and browse on 9.6-square-foot plots at each sample point.

Results and Discussion

The fire consumed 70% of the forest floor depth on area A, and 75% on area B, leaving 0.5 and 0.7 inch, respectively. In 2 years, litter on the burned areas had built up nearly to prefire levels, primarily because of a significant increase in needle drop immediately after the fire (Davis et al. 1968). However, 11 years after the fire, litter depth was less than it was 2 years after burning, probably as a result of compaction.

Eleven years after burning, the depth of the forest floor on area A was 0.8 inch, approximately 45% of the prefire depth of 1.7 inches. On area B, the depth was 1.2 inches, 40% of the prefire depth of 3.0 inches. Thus, in the 11 years since the fire, the additional needle fall that has accumulated on the 2 burned areas has been about 15% to 20% of the original forest floor depths. The current forest floor depths are approximately two-thirds those expected under unburned ponderosa pine stands of similar densities.

An unknown quantity of fire-killed twigs, branches, large limbs, and trees have fallen to the ground in the 11 years since the burn (fig. 2).

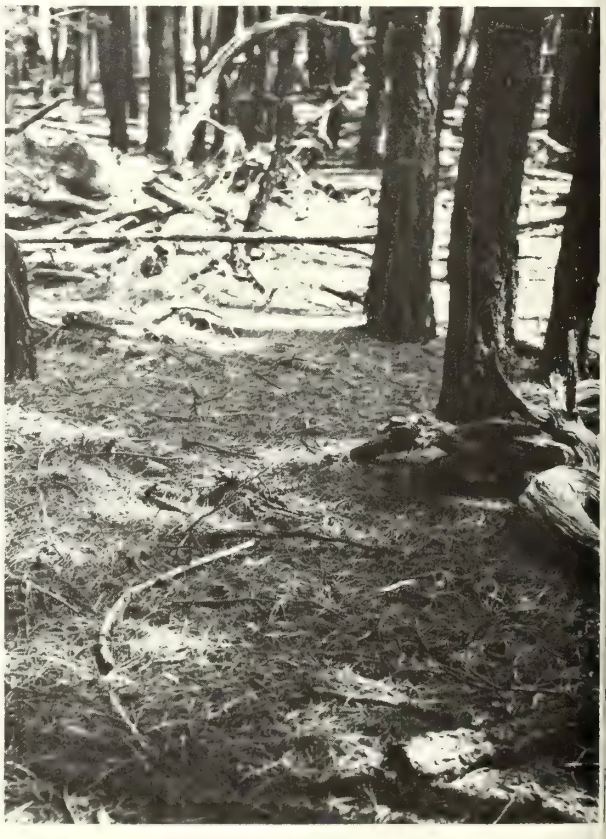


Figure 2.—Many twigs, branches, large limbs, and trees have fallen to the ground since the prescribed fire.

The general effect of the fire on the tree stand was a thinning from below. Area A lost 47% of its basal area, a reduction to 90 square feet per acre; area B lost 25%, a reduction to 235 square feet per acre. Eleven years after the fire, the basal area on area A had increased to 120 square feet per acre, indicating a growth rate of 3% annually. The basal area on B was 210 square feet per acre; however, less than that was recorded immediately after the fire. Apparently, enough trees initially damaged by the fire have subsequently died to offset the growth of residual trees.

Area A lost more of its original basal area because a greater proportion of the trees were of sapling size, which are much more susceptible to damage from ground fire than the pole size trees on area B. Both burned areas still contain too many trees for maximum wood production, however (Schubert 1974).

More ponderosa pine seedlings started on the burned areas than on adjacent unburned areas (fig. 3). One year after the fire, new seedlings occupied 85% of the mil-acre plots on area A and 95% on area B, compared with 20% and 12%, respectively, adjacent to the burned areas. Many of these seedlings were short-lived; however, established seedlings occupied only 25% of the mil-acre plots on both of the burned areas 11 years after the fire. No plots adjacent to the burns still supported seedlings.

Herbage production on area A, which increased from 3 pounds per acre before the fire to 40 pounds 1 year after the fire, was also approximately 40 pounds per acre 11 years after the fire. However, the herbage composition had changed from primarily mullein (*Verbascum thapsus*), a relatively unpalatable plant, to a mixture of bottlebrush squirreltail (*Sitanion hystrix*), mutton bluegrass (*Poa fendleriana*), showy goldeneye (*Viguiera multiflora*), red-and-yellow-pea (*Lotus wrightii*), and buckbrush (*Ceanothus fendleri*). On area B, herbage production, which had remained at the prefire level of about 5 pounds per acre 1 year after the

Figure 3.—More ponderosa pine seedlings are growing on the burned areas than on the adjacent unburned areas.

fire, increased to 17 pounds per acre 11 years after the fire. The herbage composition on area B was similar to that on area A. Generally, the grazing values must be considered negligible on the two burned areas.

Management Implications

The future of prescribed burning in southwestern ponderosa pine seems favorable. A survivor of centuries of periodic wildfires, ponderosa should benefit from carefully prescribed burning programs. Prescribed fire can reduce wildfire hazard by removing dead material, litter, and part of the forest floor. Other benefits include overstory thinning from below, site preparation for seedling establishment, and increased forage production. While forage production was inadequate for grazing on this study site, burning on more productive sites, or in lower density stands, may result in sufficient forage for wildlife or domestic grazing.

Literature Cited

Davis, James R., Peter F. Ffolliott, and Warren P. Clary.
1968. A fire prescription for consuming ponderosa pine duff. U.S. For. Serv. Res. Note RM-115, 4 p. Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colo.

Schubert, Gilbert H.
1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA For. Serv. Res. Pap. RM-123, 71 p. Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colo.

977

U S D A FOREST SERVICE
RESEARCH NOTE RM-337

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Productivity of Skidders in Selection Cuts of Southwestern Ponderosa Pine

George R. Sampson and Dennis M. Donnelly[1]

COLORADO STATE UNIVERSITY LIBRARY
JUN 7 1977
SOIL TECH. & MGT. DIV.

Productivity of five skidders differed substantially among machines and operators and was not highly predictable. Reasonable regression equations for productivity could not be developed. Actual volumes carried per turn were far below theoretical maximums. Possibilities for maximizing productivity include increasing volume carried per turn and decreasing delay time.

Keywords: Skidding (tractor), logging, timber harvesting costs.

Both forest industry and the USDA Forest Service would like to increase residual timber value by minimizing timber harvesting costs. Since yarding is the timber harvesting operation that varies the most in productivity, it seems the logical place for potential reductions. In the central and southern Rocky Mountain areas, nearly all yarding is done with tracked or rubber-tired skidders.

For all conventional Forest Service timber sales, a skidding cost is determined before the timber is offered for bid. In Forest Service Region 3 (Arizona and New Mexico), skidding cost estimates are derived from regional average cost, with adjustments for deviations in volume per acre, volume per piece, uphill and downhill skid distance and slope, and defect deductions (USDA FS 1972). This Note discusses means for improving skidder productivity rather than presenting alternative procedures for estimating skidding costs.

[1]*Market Analyst and Associate Systems Analyst at the Station's Research Work Unit at Fort Collins, Colorado. Station's central headquarters is maintained at Fort Collins in cooperation with Colorado State University.*

Considering Operations Theoretically

A basic premise in analyzing skidder productivity is that the skidder operator will attempt to maximize production over time while meeting the constraints imposed by safety considerations and good cleanup. Employees paid by the hour, as most skidder operators are, do not have a direct incentive for maximizing production. Good supervision and the desire to "please the boss," however, should provide an indirect incentive. But even if all skidder operators were equally motivated and supervised, individual skills would create differences in productivity. Previous research has found that 30 to 40 percent of production variation may result from differences in operator skill and motivation (Bennett and Winer 1964, Bartholomew et al. 1965). Cottell et al. (1971) found that the efforts of the skidding crew apparently varied in response to different physical, physiological, and psychological conditions. Another study (Cottell and Winer 1969) concluded that operator influences on productivity become more acute as mechanization increases. If we can account for this variation in operation skills, it should be possible to predict

maximum productivity, given the characteristics of the skid tractor, timber, and terrain. Characteristics of the skid tractor that must be considered are the drawbar or pulling power, running speed in each gear, and slippage of wheels or tracks. Timber characteristics include volume per piece, volume per tree, pieces per acre to be skidded, and density of the residual stand. Terrain factors include skid distance, steepness of slopes over which timber is skidded, and surface condition of the ground. Gardner (1968) and Schillings (1969) indicated that the primary factors affecting productivity of crawler tractors are average skid distance, soil and surface characteristics, slope, operator efficiency, fixed time per turn, and volume per turn.

In examining skidder productivity and potential for improvement, the skid cycle time may be divided into outbound (away from deck) time, bunch and hook time, inbound (to deck) time, unhook time, decking time, and delay time.

Outbound time is a function of distance and rate of travel. Operators have long recognized that distance from tree to log deck affects skidding productivity even though the exact relationship is not known. One study concluded that the speed and versatility of the rubber-tired skidder may have downgraded the importance of skid distance over a normal operating range (Bennett et al. 1965). The actual effect of distance is determined by the interaction with the other variables. Speed rate is affected by surface condition and slope, and can be limited by rocks, timber density, and brush that makes locating logs difficult. **Inbound time** is affected by the same variables; in addition, inbound speed can be affected by weight of the load being skidded. In general, skidder speeds (particularly outbound speeds) are limited by safety and operator comfort rather than power. Previous investigators have also reached this conclusion (Phillips and Spray 1966).

Bunch and hook time are affected by volume per piece and distance between felled trees. These factors influence bunch and hook time for both grapple and cable skidders, although the exact effect is different for each skidder type. For grapple skidders, location of the log with respect to the skid trail has relatively more effect, since the grapple skidder must travel to each log. Travel between trees while bunching and hooking can also be affected by terrain, surface condition, and timber density. **Unhook time** is usually constant for a grapple skidder. For cable skidders, unhook time is a function of the number of pieces skidded, or number of chokers used if there are two or more pieces per choker. **Decking time** is a function of volume per deck and height of deck. Generally, average time per turn spent decking will increase with deck height and size. **Delay time** includes all time spent idle due to breakdowns, fueling, personnel breaks, and waiting in queues at the log deck. Skidder breakdowns can be minimized by preventive maintenance and careful operation. Waiting time at the log deck can be minimized by having skidder operators drop their loads at an alternative location close to the log deck if there is another skidder at the deck (providing one or more of the skidders is a grapple skidder so the load can be easily regrappled and moved when the deck area is clear).

Optimum skidding production is achieved when volume per unit of total skid cycle time is maximized. Maximum production per unit of time under any given situation can be obtained by maximizing the volume skidded per unit of inbound time where distances between harvested trees are not great. This maximum will occur at the lowest gear of the skidder, assuming the log load is also the maximum the skidder can carry. If speed is doubled, for example, more than half of the available skidding power is lost. Sacrificing load size to increase speed therefore reduces volume per unit of inbound time and productivity. Cost per unit of volume skidded will be minimized when volume per unit of inbound time is maximized.

In practice, accelerating, traversing rough ground, avoiding obstacles, and slowing down for approaches to the log deck prevent traveling at the highest theoretical speed when loads are light. Lower speeds with heavier loads are more efficient. Attempting to achieve the absolute maximum weight that can be skidded, however, may result in higher hooking costs if time is spent searching for the right size logs, or in overloads that might cause equipment breakdown. For partial cuts, the increased distance between logs may become a limiting factor in hooking the maximum loads. In instances where short or small-diameter pieces are being skidded, the size of the grapple opening or the number of chokers will limit the load weight to less than maximum levels.

The maximum load for any given set of circumstances is difficult to determine. Knowledge is lacking on the actual coefficient of skidding resistance (coefficient of friction and resistance resulting from gouging action of the dragging logs), tractive efficiency of the skidder, and variation in slope from woods to landing or log deck, particularly as affected by skid road placement and alinement. However, by using assumptions for the above factors, a theoretical maximum load can be computed.

Load capacity depends to some extent on characteristics of the logs in the load and exactly how they are skidded. Garlicki and Calvert (1968)

found that for tree lengths, less power was needed if logs were skidded butt first with the butt end suspended. They also found that skidding whole trees consumed twice as much power as skidding tree-length logs (Garlicki and Calvert 1969).

Analyzing Skidder Productivity

During the summer of 1973, time and motion data were taken on five skidders in Arizona (table 1). Saw logs and pulpwood from a selection cut on a ponderosa pine site were being skidded and decked together. All skidders were intermediate size (90-140 net flywheel horsepower). Machines 1, 2, and 3 were rubber-tired skidders with grapples; machine 4 was a crawler with chokers; and machine 5 was a rubber-tired skidder with chokers. Four machine operators had at least one season's experience; operator 5 had only 2 weeks' experience. Skidders 1 through 4 were skidding to the same log deck. Skidder 5 was operating in the same timber type, but was not part of the regular crew and was skidding to a separate log deck.

To determine theoretical capacity, detailed data were taken on skidders 1 and 2. Both skidders operated in the same type of terrain and close to each other. Skidder 1 was rated at 120 net flywheel horsepower; skidder 2 at 94. Based on data in table 1, skidder 1 averaged about 510 ft^3 per working hour, and skidder 2, about 270. Differences in productivity were partly due to power differences between machines and partly to differences in operator performance. Skidder 1 passed up some small logs in favor of hauling larger and more distant logs, while skidders 2 and 3 brought in the remaining logs and in general worked the areas containing smaller timber. Timber on steep pitches or otherwise hard to harvest was left for the crawler (skidder 4) since it was the only one of the four skidders with chokers. Generally, these difficult areas were farthest from the roads.

Variables measured for each turn included: (1) travel time and distance from the log deck to the location of the first log picked up for that turn, (2) time spent and distance traveled grappling and traveling between logs, (3) inbound time and distance from the last log grappled or hooked to the log deck, and (4) time spent decking or piling logs. Delay time during each turn was also recorded. For each part of the skidding cycle — outbound, hook, and inbound time — data were taken on average slope, surface type (obstacles to skidding), surface condition (dry, wet, and so forth), and brush density. For each turn, the length of each log with the diameters of each end were measured, and the approximate cubic volume of wood was computed using the formula for a frustum of a cone.

Data were taken on separate turns to avoid using data for load volumes and skid distances averaged over a period of time. Obviously, delay time and deck time do not occur on every turn and are subject to a very high variance if computed on a turn basis. Therefore, only outbound time, hookup time, and inbound time (exclusive of obvious delays) were included in the regression analysis.

Table 1.--Average value of variables for five skidders yarding sawtimber and pulpwood on the same site in Arizona, 1973

Skidder and type	Distance traveled			Volume		Travel speed		Time				Turns		Productivity/ working hour	
	Outbound	Hooking	Inbound	Per skid turn	Per piece	Empty	Loaded	Hook time/ piece	Delay time/ turn	Deck time/ turn	Total time/ turn	Total/ hour	Pieces/ turn	Pieces	Volume
	-- *Yards* --			*ft^3*		*m/h*		---- *Minutes* ---				- *No.* -		*No.*	*ft^3*
SKIDDER 1 (rubber-tired; grapple)	76.6	42.0	88.7	75.2	25.2	2.0	2.4	1.0	2.8	0.6	8.8	6.8	3.0	20.0	510
SKIDDER 2 (rubber-tired; grapple)	57.7	18.6	54.8	39.7	14.3	1.8	1.8	1.0	3.5	.6	8.8	6.8	2.8	19.0	270
SKIDDER 3 (rubber-tired; grapple)	108.6	41.5	100.7	34.8	11.5	1.9	2.9	1.7	4.7	.8	13.7	4.4	3.0	13.3	150
SKIDDER 4 (crawler; choker)	177.1	43.8	186.3	87.9	16.3	1.4	1.6	1.4	9.6	1.1	26.6	2.3	5.4	12.1	200
SKIDDER 5 (rubber-tired; choker)	91.8	7.7	75.8	55.1	21.1	1.5	2.0	1.6	1.6	1.7	10.9	5.5	2.6	14.4	300

Independent variables that were significant in predicting time per turn included inbound distance, distance traveled while hooking logs, slope percent in the areas where logs were being hooked, and a subjective rating from 1 to 3 based on increasing obstacles to travel (rocks, down timber, and so forth). The regression coefficient of determination (R^2) was not acceptable for some skidders. R^2 values ranged from 0.43 to 0.71. No method for determining independent variable values was consistently reliable. This, coupled with wide and unpredictable variations in volume per turn, rendered the prediction equations unreliable.

Improving Productivity and Reducing Skidding Costs

If average productivity of each skidder is used as a gage, possibilities for improving productivity become apparent. Some skidders operate erratically, particularly with regard to volume skidded during any particular turn (see table 1). Skidder productivity could be improved by making and enforcing some general operating rules.

Some of the variables, however, reflect conditions that the operator cannot control. For example, volume per piece cannot be increased on the area as a whole unless bucking to longer lengths were possible. Likewise, skidding distance cannot be changed unless options exist for spacing log decks and/or spur roads closer together, as discussed later. Remaining major means of increasing productivity, then, are decreasing hook time per piece, reducing delay time, and increasing volume per turn.

Since hook time is determined primarily by location of the log with respect to the skid trail, residual stand of surrounding timber, and the local terrain, few chances for improvement exist. However, the practice of one skidder searching out only big logs increases distance traveled hooking — a practice which probably increases total hook time for all skidders in the crew and the likelihood that some logs will be missed. For cable skidders operating on short distances, employing a chokersetter to preset chokers may be practical to reduce the operator's hooking time. Chokersetters were not being used on the operation we evaluated, however.

Delay time occurs when skidders either wait for another skidder to clear the deck area or they stop enroute to chat about the location of logs yet to be skidded. With grapple skidders, time could be saved by dropping the load and regrappling it later when the deck area is clear instead of waiting for access to the deck. A clear decking strategy and protocol should prevent most delays at the deck. Delays to discuss the location of remaining logs could be avoided by assigning each skidder to a designated sector. This would also allow each operator to mentally build his next load as he is bringing in the current one, since no logs would be removed from the immediate area before he returned. Operator 5, who was skidding in a location away from the other skidders, had the least delay time even though he was inexperienced (see table 1). This illustrates the need for more planning in design of landings and the associated skidder traffic pattern.

How much the volume per turn could have been increased cannot be inferred from the data. Skidders 1 and 2 appeared to be hauling loads far below capacity (fig. 1) as well as far below the theoretical maximum volume for the slope. The 50 percent theoretical maximum load that could have been skidded by each machine for given speeds for these same slope classes assumes a coefficient of skidding resistance of 0.70 and a weight of 59 pounds of wood plus bark for each cubic foot of solid wood. Average volumes per load by slope class (fig. 1) indicate no apparent relationship between what could have been skidded and what actually was. The operators may have had one or more of these problems: (1) did not know their maximum load capacity, (2) did not know the weight of the load they had grappled at any particular time, (3) could not find enough logs in one location to make a larger load, or (4) were not concerned about maximizing the load. Providing operators with estimating aids and with more training should help overcome the first two problems. The third problem would be partially solved by assigning skidders to sectors, but more research is needed to determine the relationship of log size and log density to the optimum load for a given skidder. For various spatial distributions of logs, guidelines are needed to determine when to bring in a light load instead of searching for additional logs to bring the load closer to the maximum weight.

The fourth problem, lack of motivation, undoubtedly exists to some degree in all harvesting crews. Adequate training may increase crew member motivation by creating an aura of professionalism, although this has not been proven. Other more direct incentives may be required.

Although most of the concern above has been with skidders carrying far less than their capacity, overloading can result in equipment breakdown and costly delays. For properly maintained equipment, however, improper use such as jerky starts or excessive speeds is more likely to cause breakdowns than overloading.

Pay incentives for skidder operators, based on volume or number of pieces, would help overcome lack of concern over productivity, but this

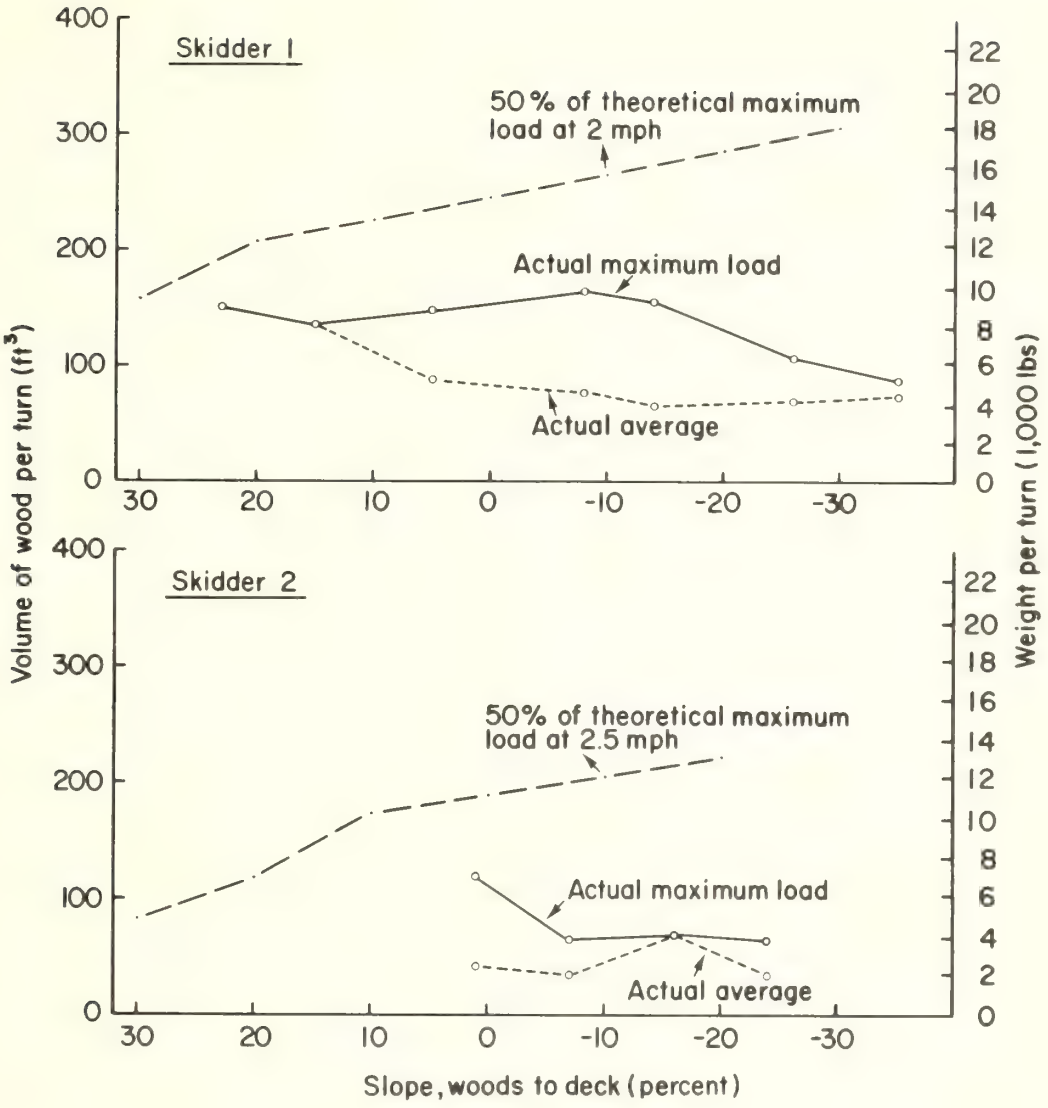


Figure 1.—Loads per turn for two skidders, with theoretical maximum, actual maximum, and average volume by percent slope.

approach is not common in the central and southern Rockies.

The above discussion pertains to improving skidding productivity on an ongoing timber sale where roads were already located, and road costs were not considered. In practice, the goal is actually to minimize the unit cost of skidding plus road construction. The general relationship between skidding costs, road construction costs, and the total of the two is shown in figure 2 for gentle terrain where road location is optional. Distances that skidders actually travel are affected not only by road spacing, but also by deck spacing along the road and the efficiency with which skidders travel between log decks and timber to be skidded.

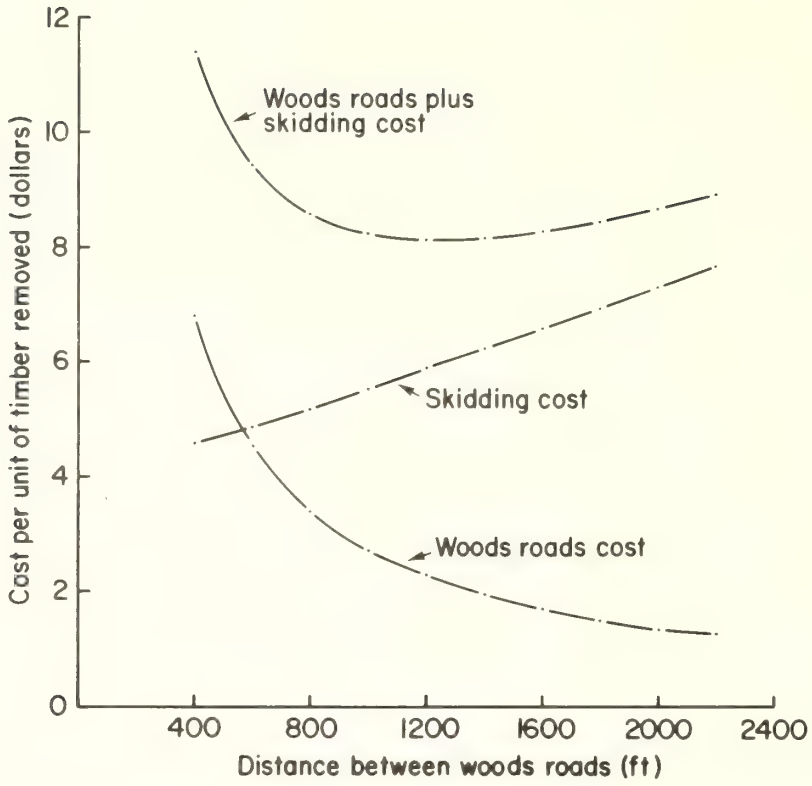


Figure 2.—General relationship of skidding costs to construction and spacing of woods roads for a hypothetical situation.

Summary and Conclusions

Given the pertinent skidder characteristics of weight, power, and traction plus precise data on slope, size distribution, and spatial distribution of the timber to be skidded, the time per turn, volume per turn, and volume per hour become precisely determinable. However, for most logging chances, determining values for all of the above independent variables is not practicable.

To investigate skidder productivity, data were taken for four rubber-tired skidders and one crawler skidder that were yarding selection-cut ponderosa pine. Detailed data were taken for two of the rubber-tired skidders that were equipped with grapples. One skidder was rated at 120 and the other at 94 net flywheel horsepower. Regression equations developed for each of the skidders from data taken on a turn basis did not satisfactorily predict performance. Part of this could be attributed to skidder operators who did not perform consistently, although they seemed to be typical of operators observed on other areas. The operator of the larger skidder tended to search out the largest pieces and, hence, traveled greater distances and carried larger loads. Both skidders carried loads far below the theoretical maximum, part of which could be attributable to the spatial distribution of the timber.

Major opportunities for increasing skidder productivity appear to be (1) increasing the volume carried per turn, and (2) decreasing delay time. Operators should know the general volume range that their machines are capable of skidding over any given type of terrain. They must also be able to estimate the volume that they have hooked or grappled at any particular time, and the likelihood of finding one or more logs nearby that can be skidded without overloading. If greater volumes per turn are not possible due to spatial distribution of timber on the site, smaller, less expensive skidders may be able to maintain the same productivity, but at a lower cost per unit of volume.

The most common delays were skidders interfering with each other both in the field and at the log deck. These delays could be minimized if skidders were assigned to different sectors, and if operators were instructed to drop their load nearby when the landing was occupied.

Literature Cited

Bartholomew, A., W. D. Bennett, and H. I. Winer.
1965. Factors affecting productivity of wheeled skidders. Pulp Pap. Mag. Can., Woodl. Rev., 66(4): WR200, 202, 204, 206.

Bennett, W. D., and H. I. Winer.
1964. A study of environmental factors and their effect on the productivity of tree-length skidding. Pulp Pap. Res. Inst. Can., Res. Note 47, 19 p. (Woodl. Res. Index 160), Montreal, Can.

Bennett, W. D., H. I. Winer, and A. Bartholomew.
1965. Measurement of environmental factors and their effect on the productivity of tree-length logging with rubber-tired skidders. Pulp Pap. Res. Inst. Can., Tech. Rep. 416, 49 p. + app. (Woodl. Res. Index 166), Montreal, Can.

Cottell, P. L., and H. I. Winer.
1969. Alternative methods for evaluating the productivity of logging operations: Implications of a study of wheeled skidding. Pulp Pap. Res. Inst. Can., Woodl. Pap. W.P. 14, 10 p. Pointe Claire, P.Q., Can.

Cottell, P. I., H. I. Winer, and A. Bartholomew.
1971. Alternative methods for evaluating the productivity of logging operations: Report on a study of wheeled skidding. Pulp. Pap. Res. Inst. Can., Woodl. Rep. WR/37. 28 p. + app. Pointe Claire, P.Q., Can.

Gardner, Rulon B.
1968. Exploratory analysis of crawler-tractor skidding in Montana. Trans. Am. Soc. Agric. Eng. 11(1):138-141.

Garlicki, A. M., and W. W. Calvert.
1968. Effect of tree-length orientation on skidding forces. For. Prod. J. 18(7):37-38.

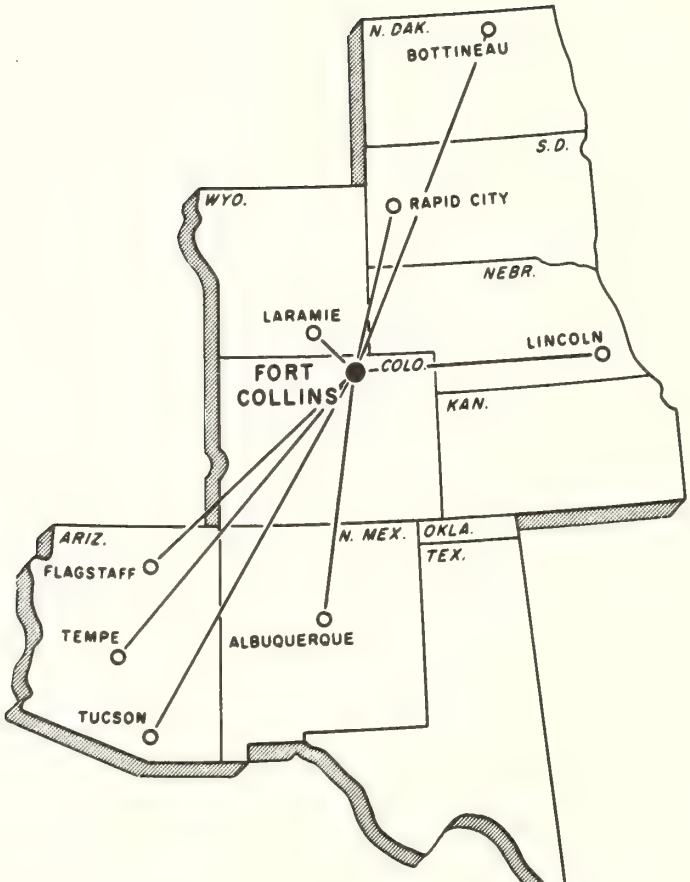
Garlicki, A. M., and W. W. Calvert.
1969. A comparison of power requirements for full-tree versus tree-length skidding. Pulp Pap. Mag. Can., Woodl. Sect. 70:83-86.

Phillips, Ross A., and Richard A. Spray.
1966. Wheeled skidder performance. *In* Proc. First Annu. For. Eng. Symp., 1966. W. Va. Univ., Tech. Bull. 82. p. 39-49.

Schillings, Paul L.
1969. Selecting crawler skidders by comparing relative operating costs. U.S. Dep. Agric. For. Serv. Res. Pap. INT-59, 20 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

U.S. Department of Agriculture, Forest Service.
1972. Timber appraisal handbook, FSH2409.22 R-3 as amended. U.S. Dep. Agric., For. Serv., Region Three. Albuquerque, N.M.

Agriculture—CSU, Fort Collins


N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT
COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON

1977

USDA FOREST SERVICE
RESEARCH NOTE RM-338

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Lighted Collars to Aid Night Observations of Mule Deer

Len H. Carpenter[1], Donald W. Reichert[2], and Frank Wolfe, Jr.[2]

JUN 7 1977

Neck collars with lights were developed which permitted mule deer (*Odocoileus hemionus*) to be identified and observed at night. The light intensity and/or blinking sequence of the battery-powered neon lights was varied to allow identification of four individuals. Collars cost approximately $80 each.

Keywords: *Odocoileus hemionus*, night observation.

Wildlife managers and researchers have been limited in behavioral studies of animals by their inability to conduct accurate observations at night. Various systems have been used to monitor nighttime activities of different wildlife species (Richter 1955, Ozoga and Gysel 1965, Swanson and Sargeant 1972, and Reed et al. 1973). A major difficulty with any system is identification of individual animals.

Dr. K. E. Hungerford, University of Idaho, originally suggested using a harness or collar, with a battery-powered blinking neon light attached, that fitted on the animal. Prenzlow (1968, 1969) pursued this idea, and developed pulsating light units attached to neck collars that allowed identification of individual elk in pens.

The development of an identification system based on pulsating neon light units attached to deer neck collars is described here. This system permitted 24-hour observation of daily activities of four individual deer during three weekly periods in January and February 1976. These observations are part of a cooperative research study conducted by the Colorado Division of Wildlife and Rocky Mountain Forest and Range Experiment Station to estimate the capacity of winter ranges to support mule deer.

Study Area and Methods

Four tame, trained (Reichert 1972) mule deer (*Odocoileus hemionus*) were enclosed in a 4-ha pasture at the Junction Butte Research Center near Kremmling, Colorado for 45 days. The pasture is located on typical big sagebrush (*Artemisia tridentata*) winter range on a gently sloping southwestern aspect.

Deer were observed 24 hours a day for 5 consecutive days during periods January 11-16, 25-30, and February 8-13, 1976. Four observers, each working 6 hours, observed the deer from a 4.6-m high observation tower, centrally located to permit maximum visibility. Maximum distance from the tower to any point in the pasture was 250 m. A model 221 night viewing device developed by Appollo Lasers, Javelin Division of

[1] *Wildlife Researcher with the Colorado Division of Wildlife in Kremmling, Colorado 80459.*

[2] *Range Research Technician and Electronics Technician, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Los Angeles, California[3], equipped with a 300-mm telephoto lens, was used to monitor nighttime activities of the deer.

Each deer was fitted with a collar equipped with four battery-operated neon lights (fig. 1) designed to give separate light sequences and intensities. Light intensity and/or flash sequences

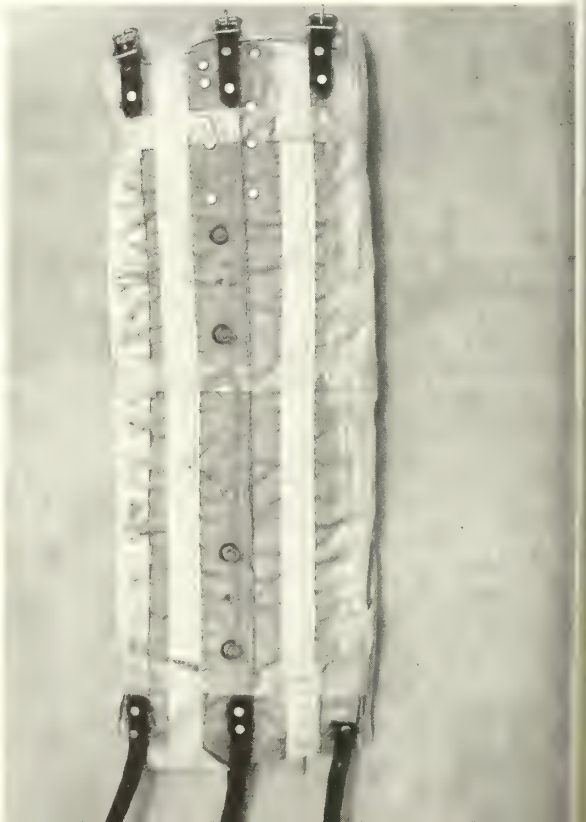
Figure 1.—Tame mule deer with collar and attached lights.

identified individual deer. Two lamps were positioned on each side of the collar, either parallel or perpendicular to the axis of the deer's neck, to give the following four light patterns: (1) parallel with all lamps constantly lighted (fig. 2); (2) perpendicular with two lamps constantly lighted and two lamps blinking slowly (1 blink per 2 sec) (fig. 3); (3) perpendicular with all lamps blinking rapidly (2 blinks per sec); (4) parallel with all lamps blinking slowly (1 blink per 2 sec). Light intensity of neon lamps was determined by maximum light tolerable to the night viewing device. The four collars were of different colors to aid in identification of deer during daylight.

[3]*Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Dep. Agric., or Colo. Div. of Wildlife.*

Figure 2.—Position of 4 lamps on neck collars. (Lights shown in "parallel" pattern).

Figure 3.—Leather straps with buckles were attached to each collar to facilitate application and removal. (Lights shown in "perpendicular" pattern).



Collar Construction and Design

To accommodate electrical components, two standard polyvinyl deer neck collars each 17.8 by 55.9 cm were stitched together to form one collar 35.6 cm wide. Three adjustable leather straps with buckles were riveted to each collar (fig. 3). Four holes were punched into each collar and fitted with lamp holders to secure lamps. Seven battery holders with 22.5-volt batteries were riveted on the inside of the collar to provide a series hookup of 157.5 volts. This voltage was necessary to activate four neon lamps and maximize life expectancy of each collar. Electrical connections were soldered to insure reliability of the units, and all exposed wires, sockets, and batteries were protected by wrapping with reinforced fiberglass tape. A covering of foam rubber 2.5 cm thick was secured to the inside of the collar. This material protected the deer from the attached hardware, and served as heat and moisture insulation for the electronic components.

Four capacitors (1 mfd 200) and four resistors (0.5 watt) were used for blinking light circuits. The resistor regulated the current and the time needed to charge the capacitor to a minimum of 105 volts. Once charged, the lamp flashed, discharging the capacitor; the sequence was repeated as long as batteries maintained necessary current. The blinking rate was determined by R x C = T; where R = resistance, C = capacitance and T = time. The intensity of light for constant-light circuits (fig. 4) was determined by the value of the resistor. Weight of each collar fully equipped was approximately 690 grams. Materials and costs for each collar are presented in table 1.

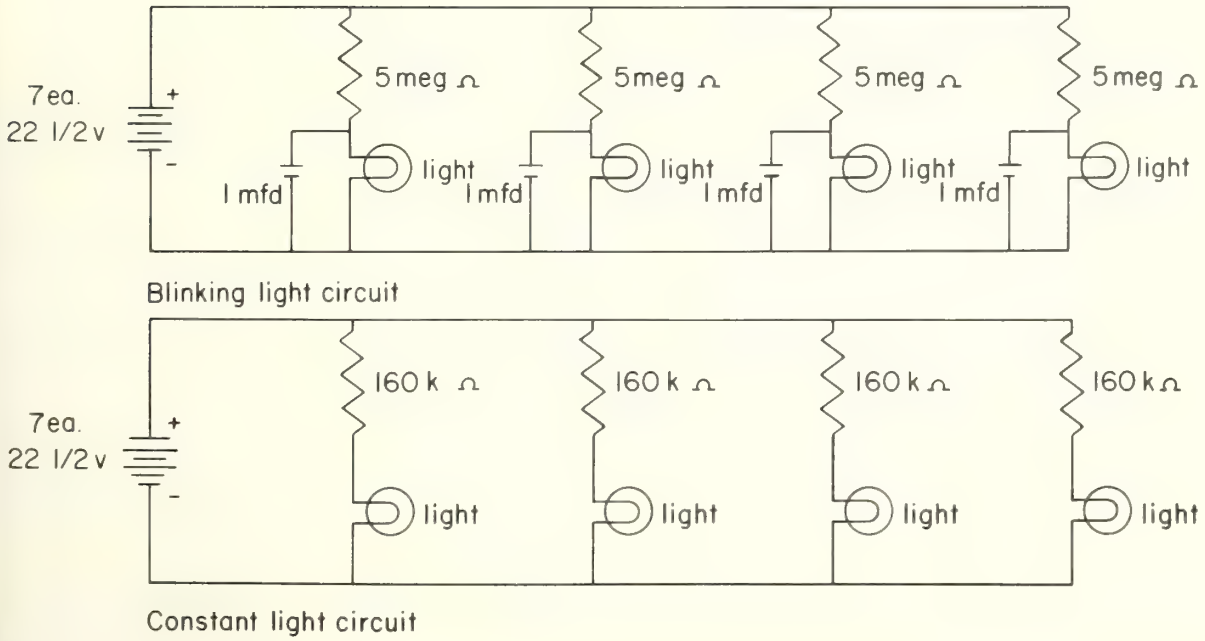


Figure 4.—Electronic circuits of constant and pulsating-light deer collars.

Table 1.—Total listing of materials and costs for the described collars.

No.	Item	Description	Unit cost	Total
2	Collars	Polyvinyl impregnated nylon (10.2 by 55.9 cm)	$3.68	$ 7.36
4	Lenses	Type 137-0937 clear	.51	2.04
4	Lamps	Type N E2J (C 9 A) 105-125 volts, ¼ watt	1.60	6.40
4	Lamp holders	Neon Subminiature Type 137-8864-09-532	3.41	13.64
7	Batteries	22½ volt M-505 Mallory electronic	2.00	14.00
2	Holders	Number 182 Keystone battery	.74	1.48
3	Buckles	1.3 cm roller	.10	.30
1	Strap	Leather (1.3 by 81.3 cm)	.60	.60
22	Rivets	.79 cm tubular	.02	.44
1	Foam rubber	1.3 by 20.4 by 55.9 cm	.50	.50
1	Tape	Roll of 2.54-cm filament reinforcing	.76	.76
2	Hours (labor)	Contract for leather, rivet work	7.50	15.00
4	Resistors	½ watt ± 10% tolerance	.28	1.12
	Wire	¼-spool, 20-gage Belden electrical	7.44	1.86
	Solder	20-gage, 5-core, ¼-pound spool multicore resin flux	4.34	1.10
			Total for constant light collars	$66.60
4	Capacitors	1 mfd 200 volts (Blinking light collars only)	2.73	10.92
			Total for blinking light collars	$77.52

Performance

The only major problem encountered with the collars was short-circuiting during an unseasonal rainstorm. Snow was never a problem. It is suggested that future units be encased in clear resin or dental acrylic (Mech et al. 1965) to insure durability and resistance to moisture. A minor problem was caused by deer chewing on the leather straps, but this was minimized by shortening the straps. The life of the straps was prolonged by dressing the leather with silicone.

Collars with blinking lights performed 6 to 8 months on one set of batteries, but longevity of the constant-light collars was 6 days or less. Reducing the number of lamps from 4 to 2 increased the battery life on constant-light collars about 24 hours. A light-sensitive switch which would turn off lights during daylight hours could double battery longevity. Additional lamp patterns, sequences, and/or intensities could easily be designed to increase the number of distinguishable animals.

Literature Cited

Mech, L. D., V. B. Kuechle, D. W. Warner, and J. R. Tester.
1965. A collar for attaching radio transmitters to rabbits, hares, and raccoons. J. Wildl. Manage. 29(4):898-902.

Ozoga, J. J., and L. W. Gysel.
1965. A mechanical recorder for measuring deer activity. J. Wildl. Manage. 29(3):632-634.

Prenzlow, E. J.
1968. Experimental telemetering devices. Colo. Game, Fish and Parks, Game Res. Sec., Fed. Aid Proj. W-38-R. Game Res. Rep., July, Part 3, p. 237-274.

Prenzlow, E. J.
1969. A pulsating light for identifying animals at night. Colo. Div. of Game, Fish and Parks. Game Inform. Leafl. 94. 3 p.

Reed, D. F., T. M. Pojar, and T. N. Woodard.
1973. A video timelapse system for wildlife surveillance. Colo. Div. of Game and Parks. Game Inform. Leafl. 94. 3 p.

Reichert, D. W.
1972. Rearing and training deer for food habits studies. USDA For. Serv. Res. Note RM-208, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Richter, W. C.
1955. A technique for night identification of animals. J. Wildl. Manage. 19(1):159-160.

Swanson, G. A., A. B. Sargeant.
1972. Observation of nighttime behavior of ducks. J. Wildl. Manage. 36(3):959-961.

1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-339

REST SERVICE
. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Solar Radiation Measurement in Northern Arizona

R. E. Campbell and O. G. Stevenson[1]

NORTHERN ARIZONA UNIVERSITY LIBRARY
JUN 2 1977
FLAGSTAFF, ARIZONA

Radiation on clear days averaged about 78% of the extra-terrestrial value. Mean monthly radiation varied from 57% in July to 75% in June. The mean radiation for the 2-year period was 67% of extra-terrestrial. Daily radiation varied from 24 langleys for a day in January to 836 for a day in June; January mean radiation was 272 langleys/day, while the June mean was 736. Measured transmissivity is related to hours of sunshine, but the relation is not close enough for precise daily predictions.

Keywords: Solar radiation.

Introduction

Solar energy is the driving force of all the natural processes going on around us. At a given point above the earth's atmosphere, insolation on a horizontal surface (extra-terrestrial radiation) can be predicted, given latitude, date, and time. Indeed, a number of people have presented calculations and some have written computer programs to do this (Buffo et al. 1972, Frank and Lee 1966, Furnival et al. 1969, McCullough and Porter 1971). The calculations are based primarily on computations of Milankovitch (1930). A solar constant — that is, intensity of solar radiation outside the earth's atmosphere, normal to the sun's beam at the mean distance of the earth from the sun — has been developed by the Smithsonian Institution and others (List 1963). A value of 1.94 langleys/min is generally assumed. This value, equivalent to 1.353 kilowatts/m^2, has recently been confirmed from satellites and high-altitude aircraft (Duffie and Bechman 1976).

Actual radiation received at the ground varies with atmospheric conditions, however. Fairly predictable factors include Rayleigh, aerosol, and ozone distributions (Elterman 1968). The greatest — and most unpredictable — factor, however, is atmospheric moisture, which can exclude nearly all incoming infrared radiation. Whether solar energy is used by forests, range plants, irrigated agriculture, or by man for heating, knowledge of day-to-day fluctuations is important to the management of these uses. Handy and Durrenberger (1976) measured solar radiation and sunshine data received at 21 locations in the Southwest, including 8 in Arizona. Our data, for a location 20 miles south of Flagstaff, supplement those of Handy and Durrenberger.

Instrumentation

Sensing units were mounted on a horizontal platform on a 10-m tower in a forest clearing 20 miles due south of Flagstaff to measure shortwave solar radiation (0.2 to 2.5 micron (μ) wave lengths). The data are to be used primarily in various aspects of forest ecosystem modeling.

[1] *Research soil scientist and forestry technician, respectively, located at Rocky Mountain Forest and Range Experiment Station's research work unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

The solar radiation we measure represents the combined direct-beam and diffuse components of the incoming radiant energy received at the forest canopy level, on a horizontal surface. It is reported in units of langleys (gram-cal/cm^2)/day (Delinger 1976), and is interpreted in respect to extra-terrestrial radiation received outside the atmosphere, and in respect to possible sunshine.[2]

Two systems were used for collecting the data. The first was an Eppley model 50 pyranometer (also known as a Kimball and Hobbs pyrheliometer). The signal from the pyranometer was transmitted to an analog stripchart recorder. The area under the analog curve was digitized on an hourly basis, and from these figures daily totals were obtained.

The second system consisted of a Kipp CM-5 solarimeter (a Moll-Gorczynski type pyranometer) connected to a Lintronic digital volt-time integrator. This instrument printed hourly integrated values on paper tape. Both sensing instruments were calibrated according to the 1956 international pyrheliometer scale.

The glass instrument domes are transparent to the lower limit of ultraviolet radiation received at the earth's surface, which is about 0.29 μ, through the visible spectrum (0.4 to 0.7 μ) and into the infrared wavelengths. However, they are not transparent to the longer infrared rays beyond 2.8 μ or 3.0 μ. Because of this upper limitation, the instruments are said to be sensitive to short-wave solar radiation. Radiometers with plastic coverings instead of glass are transparent to the longer infrared wavelengths as well.

Because the Kipp unit, installed in late 1974, had been most recently calibrated, and the two sensors differed slightly in response, all readings from the Eppley were corrected to aline with the Kipp. The correction consisted of comparing daily readings from the two systems from February through September 1975. The resulting straight-line regression equation was $\hat{K} = 1.040E - 0.926$, where K is the Kipp reading and E is the Eppley reading in langleys/day. The regression coefficient (r) was 0.984.

Radiation Measured

The values in table 1 are mean daily corrected Eppley readings for January 1974 through January 1975, and direct Kipp readings for February 1975 through December 1975.

Radiation during December and January averaged slightly over 270 langleys/day; the low was 24 langleys. June radiation reached a high of 836, while the average for the month was 736 langleys/day.

Radiation on clear days averaged about 78% of the extra-terrestrial value. Mean monthly radiation varied from about 57% of extra-terrestrial in July to 75% in June. The mean radiation for the 2-year period was 66% of extra-terrestrial.

A plot of average daily total measured radiation (lower curve, fig. 1) for each month of the year shows a sharp dip for July due to frequent summer cloudiness. Cloudiness in March was less pronounced. Daily total radiation measured on selected clear days and average daily extra-terrestrial radiation are also shown.

The measured clear-day values, which were lower than those of Buffo et al. (1972) and Davis (personal communication), declined from about 80% of extra-terrestrial in early 1974 to about 77% in 1975. This decline probably reflects drift

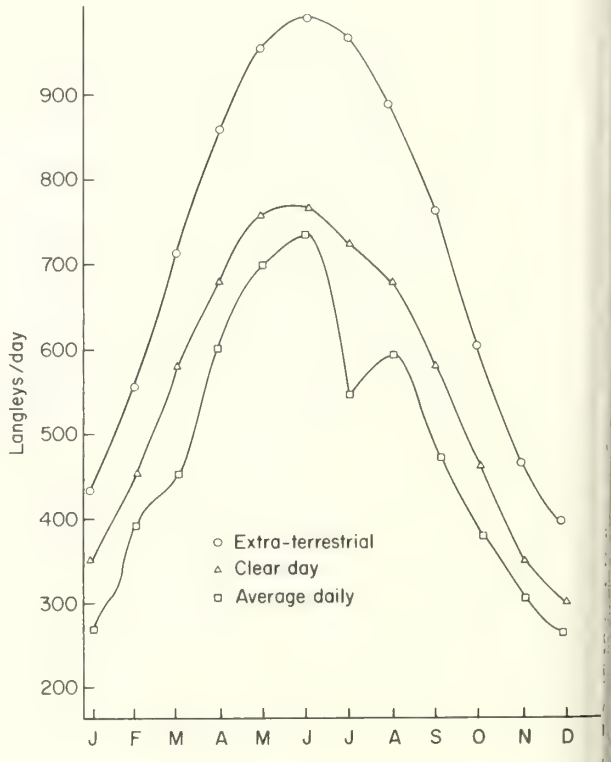


Figure 1.—Average daily extra-terrestrial, and measured clear-cay and average-day solar radiation on a horizontal surface by months near Flagstaff, Arizona. Points are average for 1974 and 1975.

[2]Some convenient conversions of langleys to other commonly used units of energy are:

100 langleys (gram-cal/cm^2)

= 368.5 BTU/ft^2
= 971.6 watt hr/yd^2
= 4.184 x 10^6 joule/m^2
= 1.162 kilowatt hr/m^2

Table 1.—Daily total short-wave solar radiation received on a horizontal surface in langleys. Site 34°55'' N latitude, 11°38' W longitude, elevation 1,977 meters (6,485 ft.), 37 kilometers (20 mi) south of Flagstaff, Arizona. Values are average for 1974 and 1975.

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Langleys						
1	82	401	486	366	714	765	723	544	521	520	248	269
2	162	360	372	524	728	741	624	556	518	520	264	316
3	344	374	498	664	750	737	497	532	366	408	284	304
4	236	318	462	682	683	698	494	523	375	512	379	232
5	222	326	412	662	618	734	565	494	572	504	354	246
6	176	406	367	524	628	754	580	623	316	290	388	294
7	180	385	460	401	706	720	405	618	324	348	372	294
8	98	435	191	482	742	758	566	521	553	416	250	314
9	169	332	259	560	743	743	730	586	471	494	374	313
10	204	314	164	480	762	790	688	623	570	454	363	313
11	298	438	334	522	758	761	587	604	600	492	378	304
12	286	394	460	476	758	680	476	634	507	263	354	224
13	300	215	405	672	732	709	520	698	420	378	350	188
14	350	304	354	669	764	740	481	626	548	482	328	298
15	352	258	526	666	742	716	462	604	526	479	353	286
16	306	294	560	652	590	750	517	614	511	470	350	310
17	238	254	590	518	456	755	554	660	406	462	259	300
18	322	443	566	575	662	660	561	628	378	432	280	298
19	350	466	487	725	678	745	556	630	404	342	350	300
20	232	484	271	699	694	760	527	548	433	304	310	230
21	246	378	576	690	598	764	614	641	562	338	340	159
22	382	486	328	634	612	690	611	600	552	229	252	304
23	365	480	574	611	654	742	508	616	523	382	348	235
24	376	510	602	467	772	744	620	579	391	428	336	320
25	375	472	446	564	776	708	498	594	511	408	320	248
26	308	498	384	634	726	763	528	516	466	320	316	213
27	305	412	582	741	762	764	343	516	503	327	216	275
28	348	474	618	743	724	728	586	642	544	212	194	251
29	386	—	618	744	740	722	485	645	472	280	242	260
30	222	—	590	738	702	750	507	645	464	292	332	314
31	320	—	621	—	780	—	621	604	—	212	—	239
Total	8,540	10,911	14,163	18,085	21,754	22,091	17,034	18,464	14,307	11,998	9,484	8,451
Mean	275	390	457	603	702	736	549	596	477	387	316	273
Std. Dev.	85	82	130	107	72	29	84	50	78	97	54	42

in sensitivity of the sensing units, and will be verified by a future calibration check.

In terms of energy received on a horizontal surface, the average daily input is about 8.5 kilowatt hrs/m^2 in June. Using flat plate collectors sloped toward the south with a slope about equal to the latitude, the average daily radiation would be somewhat greater. Even though the solar energy intensity is low, if the energy is collected from a large surface the quantities may be large. Duffie and Buckman (1976) estimate the energy incident daily on a 200-m^2 (239 yd^2) house roof in Madison, Wisconsin, is equivalent to that obtainable from about 25 gallons of oil.

Transmissivity/Sunshine

The transmissivity, T, of the atmosphere, expressed as the ratio of total daily radiation to daily extra-terrestrial radiation, was related to the percent of minutes of possible sunshine, S. The S values were those reported by the National Weather Service (USEDS 1974, 1975) at the Flagstaff airport, 15 miles north of the radiation observation site. The daily paired values were grouped by months with the 2 years pooled, and the regression equation $\hat{T} = a + bS$ was calculated. The T value is somewhat synonymous to the Q/Q_0 of Fritz and MacDonald (1949); but T will be lower since the Q_0 value was radiation received on a clear day rather than extra-terrestrial radiation. Even though considerable month-to-month variation was evident in the regressions, all the correlation coefficients were statistically significant at the 1% level (table 2).

If percent sunshine is high, the transmissivity can be estimated rather closely. When S = 100, the T value of the 12 regressions was 77.8% with

a 95% confidence interval of ± 2.2%. The extremes were 71.7% and 83.7%, a span of 12%. However, when S = 0 the average T value was 8.6% ± 5.4%. The extremes were greater; 1.4% to 31.9%, a span of 30.5%.

There are two reasons why the relation between transmissivity and percent sunshine is not closer. The first is that the percent sunshine is an off-on measurement. As a cloud of sufficient density moves between the sun and the sensor, a thermally activated switch stops the timer. However, the radiometer continues to measure radiation at a reduced level in inverse proportion to the cloud density. On the other hand, high, thin clouds do not switch off the sunshine timing meter, but measured solar radiation declines somewhat.

The second reason is that cloud cover patterns may differ slightly between the radiation measuring site and the airport 15 miles away where the sunshine is timed. The correlation coefficients were slightly higher for the winter months when cloud patterns tend to be regional, than during the summer when cloud patterns are more lo calized.

An examination of the monthly mean transmissivity in relation to monthly mean sunshine produced a regression of $\hat{T} = 29.74 + 0.448$ S, and a correlation coefficient of 0.683. With a larger sample and sensing units closer together, a coefficient more in line with that of Fritz and MacDonald (1949) might be expected.

Table 2.—Values of a and b in the regression T = a + bS, and correlation coefficient (r), pooled for 2 years of solar radiation measurements near Flagstaff, Arizona.

Month	Regression constants		Correlation coefficient
	a	b	r[1]
Jan.	14.91	0.688	0.906
Feb.	14.63	0.670	0.796
Mar.	14.60	0.640	0.741
Apr.	6.86	0.754	0.831
May	1.40	0.775	0.697
June	31.89	0.455	0.731
July	15.28	0.564	0.761
Aug.	15.75	0.594	0.783
Sept.	14.51	0.606	0.785
Oct.	7.48	0.677	0.928
Nov.	17.13	0.616	0.923
Dec.	29.50	0.463	0.667

[1]Corrected average r = 0.815

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Literature Cited

Buffo, John, Leo J. Fritschen, and James L. Murphy.
1972. Direct solar radiation on various slopes from 0 to 66 degrees north latitude. USDA For. Serv. Res. Pap. PNW-142, 74 p. Pacific Northwest For. and Range Exp. Stn., Portland, Ore.

Delinger, W. G.
1976. The definition of the langley. Solar Energy J. 18(4):369-370.

Duffie, John A., and William A. Beckman.
1976. Solar heating and cooling. Science 191(4223):143-149.

Elterman, L.
1968. UV visible and IR attenuation for latitudes to 59 km, 1968. Rep. 68-0153, 49 p. U.S. Air Force, Cambridge Res. Lab., Bedford, Mass.

Frank, Ernest C., and Richard Lee.
1966. Potential solar beam irradiation on slopes: Tables for 30 to 50 degrees latitude. U.S. For. Serv. Res. Pap. RM-18, 116 p., Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Fritz, S., and T. H. MacDonald.
1949. Average solar radiation in the U.S. Heating and Ventilating 46(7):61-64.

Furnival, George M., W. E. Reifsnyder, and T. G. Siccama.
1969. Program SOLAR-RIMCIF 009, Yale School of Forestry.

Handy, Robert M., and R. W. Durrenberger.
1976. Solar radiation and sunshine data for the southwestern United States. 1966-1974, 50 p. Sol. Energy Res. Comm., Phoenix, Ariz.

List, Robert J.
1963. Smithsonian meteorological tables. Ed. 6, revised (second reprint). The Smithson. Inst., 527 p.

McCullough, Edwin C., and Warren P. Porter.
1971. Computing clear day solar radiation spectra for the terrestrial ecological environment. Ecology 52(6):1008-1015.

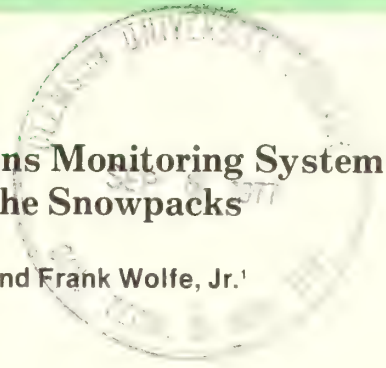
Milankovitch, M.
1930. Mathematische klimatehre. Handbuch der Klim, Bank 1, Teil A:1-176.

U.S. Environmental Data Service.
1974-75. Local climatological data, Flagstaff, Arizona. National Weather Service Office, Pulliam Airport. (Monthly, Jan. 1974 to Dec. 1975). U.S. Nat. Oceanic Atmos. Adm., Nat. Clim. Serv., Ashville, N.C.

977

U S D A FOREST SERVICE
RESEARCH NOTE RM-340

REST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION



An Acoustic Emissions Monitoring System For Avalanche Snowpacks

Donald McNair, and Frank Wolfe, Jr.[1]

Unstable snow slabs may emit characteristic sounds prior to avalanche. To test this, a low-frequency monitoring system was developed to detect acoustic emissions, and was installed at Berthoud Pass, Colorado. Geophones are located in four known avalanche slide paths. All instrumentation is described.

Keywords: Acoustic emission, avalanche prediction.

Introduction

Slab instability of snow may be correlated with the level of acoustic emissions prior to avalanche. Such a correlation would allow more accurate prediction of avalanche danger.

It is known that snow does emit sounds at high frequencies[2], but due to the poor propagation of such high frequencies through snow, they do not appear to be useful. The instrumentation described here was developed to detect acoustic emissions in the frequency range of 0.5 Hz to 3 kHz. A low-frequency recording system would also give greater coverage from a single geophone.

The system was installed at Berthoud Pass, Colorado, with geophones located in four known slide paths. Amplification, filtration, and recording instruments were located within a nearby heated instrument building. Since the distance from the slide paths to the instrument recording building was up to 400 m, a pre-amplifier was developed to transmit the signals on the long cable.

Geophones

The geophones used are Geo Space, Model Hs-1[3], with a 4.5 Hz resonance frequency. Used with 330 Ω damping resistance, their frequency is flat from 5 Hz to above 100 Hz. At 215 Hz (one octave), the response is 9.5 db down. Since no calibration equipment was available, the manufacturer's calibration was used.

[1] *Electronic Technicians, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

[2] *St. Lawrence, W., and C. Bradley. 1973. Ultrasonic emissions in snow. p. 1-6. In Advances in North American avalanche technology: 1972 symposium. USDA For. Serv. Gen. Tech. Rep. RM-3, 54 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

[3] *Trade and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

The geophones and the pre-amplifiers were mounted on 30- by 30-cm sheets of expanded metal grills. Thirty m of shielded cable supplied the pre-amplifier with ±15 V from a power supply located in a junction box, and the signal return to the junction box. The signal then was carried to the instrument recording building by up to 400 m of shielded cable. The junction boxes received 110-v a.c. power by separate conductors from the instrument recording building. The junction boxes were located at accessible points above the slide path (fig. 1).

Pre-Amplifiers

The pre-amplifiers were fabricated with Zeltex ZA801 M1 operational amplifiers. Component selection gave the desired 330 Ω input resistance to critically dampen the geophones and a nominal gain of 1,000 to drive the signal the length of the cable to the instrument recording building. A 3-kΩ resistor in series with the output was found to be necessary to stop oscillation. Pre-amplifiers were constructed on printed circuit cards made to fit in an aluminum minibox 6.4 cm wide and 4.1 cm high. This box was filled with potting compound to insure weather tightness. The pre-amplifiers were mounted with the sensor and placed in the avalanche area under the snow. The circuit is diagramed in figure 2.

The trim potentiometers were first adjusted for 0-V output with the input shorted. Calibration consisted of injecting a 1-mV peak-to-peak signal supplied by a HP 3300A function generator across the input end of the 100-ft shielded cable while varying the frequency of the input signal. The calibration range was from 0 to 10 kHz. Voltage readings were made with a Teletronix 564 oscilloscope. Typical pre-amplified calibration readings with 10-mV peak-to-peak signal input was 10.0, 8.85, and 1.6 V at frequencies of 100 Hz, 1kHz, and 10 kHz respectively.

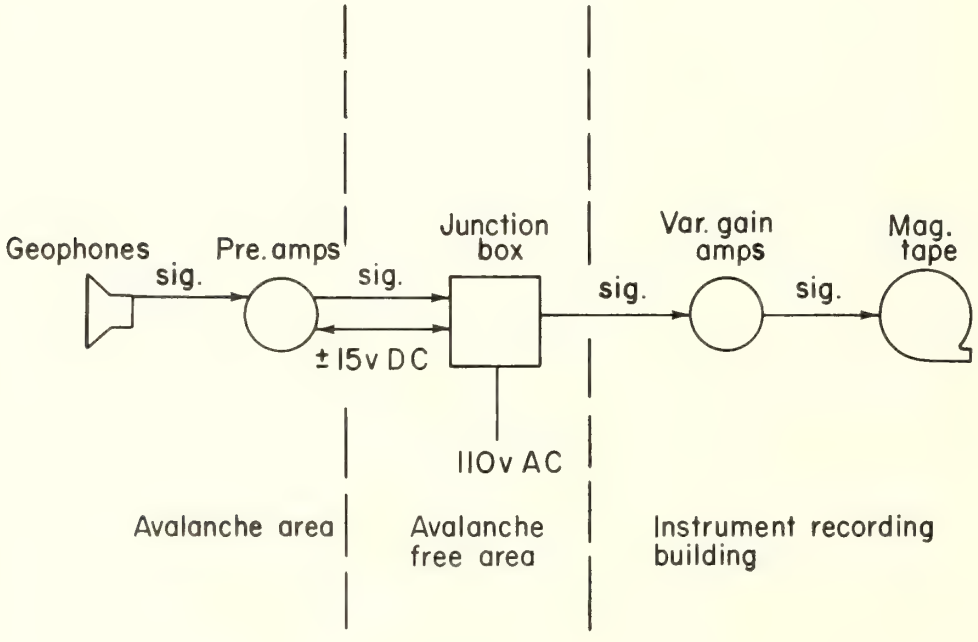


Figure 1.—Block diagram showing location of components and route of signal from geophones to recording tapes.

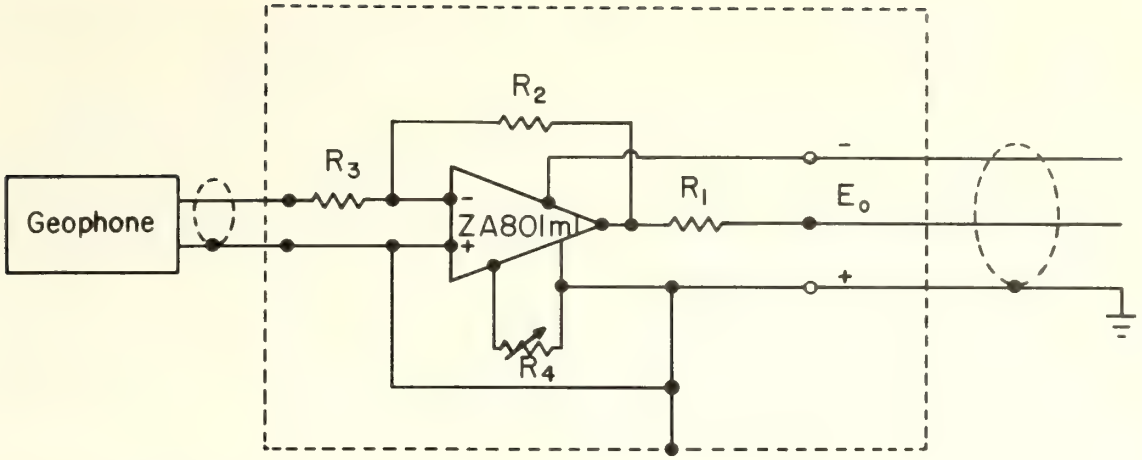


Figure 2.—Pre-amplifier components.

op — amp. — Zeltex-Za801ml
R1 — 3 kΩ, 1% tolerance
R2 — 330 kΩ, 1% tolerance
R3 — 330Ω, 1% tolerance
R4 — 10 turns, 1 kΩ

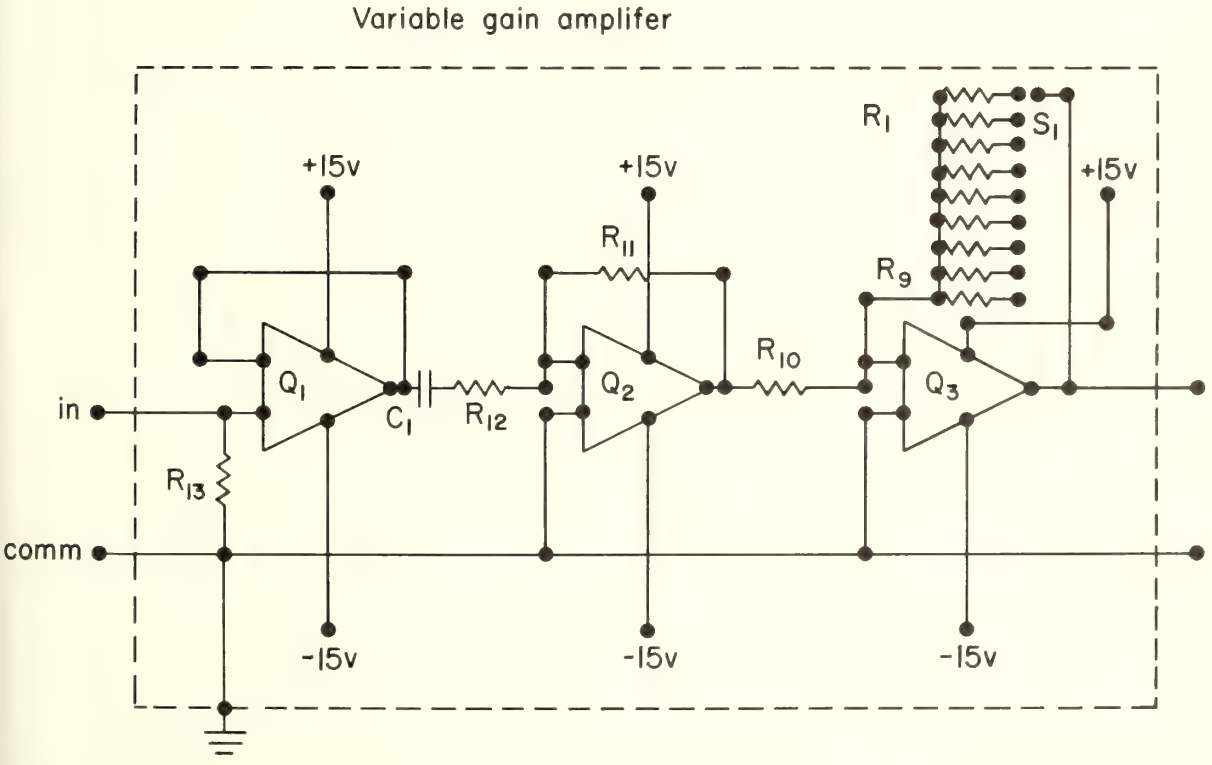


Figure 3.—Variable gain amplifier components.

R1 — 120 kΩ
R2 — 64 kΩ
R3 — 32 kΩ
R4 — 16 kΩ
R5 — 8 kΩ
R6 — 4 kΩ
R7 — 2 kΩ
R8 — 1 kΩ
R9 — 500 kΩ
R10 — 1 kΩ
R11 — 100 kΩ
R12 — 10 kΩ
R13 — 1 mΩ
S1 — spectral rotary
C1 — 25 microfarad

Note: All resistors are 1% tolerance.

Because the most sensitive scale on the Tektronic 3A7Z plug-in is only 10 mV per division, a more accurate means of measuring the input signal was needed. Using the Tektronix scope, the output signal of the HP 3300A function generator was adjusted to 1.0 V peak to peak. This voltage was then divided by a 100 ÷ 1 divider. The output from the divider was adjusted to give 0.0035 rms (10 mV peak to peak) at 100 Hz, as read on a HP 3450A voltage meter. The scope was then taken off "calibration" position and the gain potentiometer of the scope adjusted to give eight divisions, which then equaled the 1.0-V peak-to-peak signal across the input to the divider. This gave an accurate 10-mV peak-to-peak signal across the output of the divider at all frequencies by adjusting the function generator for the eight division signals across the divider input.

Rms noise measured less than 1 mV at the end of the cable with the pre-amplifier input shorted.

Variable Gain Amplifiers

The main amplifiers were fabricated with three 741 Operational Amplifiers. The amplifiers were put on printed circuit cards, with card connectors to be plugged into a grounded, shielded panel rack. B.N.C. connectors were used for input to the amplifiers and as output to the magnetic tape recorder. The outside shell was grounded. By use of a selector switch, the gain could be varied in nine steps, from X 5 to X 1200, by changing feedback to the amplifiers. These steps were made by switching through nine 1% tolerance resistors. The switch was a miniature card mount multiposition rotary. A 25-μF capacitor was placed between the first and second steps to prevent any direct current across the input from blocking the final stages (fig. 3). As seen from the calibration (table 1), this did little to upset the low-frequency response.

The calibration consisted of injecting a 10-mV peak-to-peak signal across the input, and then measuring the output with a 564 Teletronix scope. The frequencies from the HP 3300A were varied in five steps: 1, 10, and 100 Hz; and 1 and 10 kHz. The results are shown in table 1. The 10-mV peak-to-peak signal was obtained the same as the calibration of the pre-amplifiers.

The Teledyne Geo-Tech Model No. 19429 slow-speed magnetic tape recorder was run at a tape speed of .06 in per sec. Its frequency response using direct-record electronics is 0.5 to 125 Hz ± 3 db. It records 16.5 days on a 7200-ft reel of 1½ mil Ampex instrumentation tape. The recorder was capable of recording 14 channels at one time. One of these channels was used to record the binary coded time of day from a Datatron Model No. 3150 time code generator. A second channel was used to record the output from an anemometer located above one of the slide paths. The remaining 12 channels were available for recording the geophone signals. Various combinations of amplification and filtering could be used to obtain optimum signals.

Table 1.—Typical amplifier calibration (nominal gain, x 5 through x 1200) in output voltage (peak-to-peak) with 10 mV (peak-to-peak) input at various frequencies and gain settings.

	Frequency				
Gain settings	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz
1200	10.8	12.2	12.2	12.0	8.0
640	5.8	6.6	6.6	6.6	5.6
320	3.0	3.3	3.4	3.3	3.2
160	1.52	1.6	1.62	1.6	1.6
80	.75	.81	.82	.82	.82
40	.36	.41	.41	.41	.40
20	.18	.20	.20	.20	.20
10	.09	.10	.10	.10	.10
5	.042	.051	.051	.051	.051

1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-341

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating the Least Cost Combination Of Cable Yarding And Tractor Skidding For A Timber Sale Area

Dennis M. Donnelly[1]

SEP 8 1977

Estimated costs of several alternative combinations of access roads and associated tractor skidding and skyline cable yarding areas are analyzed for a 562-acre, mixed conifer watershed in Arizona. Results of this case study are extended into a general discussion of road costs, yarder size, and tractor skidding as they relate to future harvesting opportunities in central and southern Rocky Mountain forests.

Keywords: Cost minimization, logging operations design, yarding costs, tractor logging costs, logging road costs (temporary), skidding costs.

Background

Land managers have indicated that an increasing proportion of future timber supplies must come from sites with slopes exceeding 40%. In the central and southern Rocky Mountains a substantial proportion of the harvestable timber is on such sites. Harvesting this overmature and mature timber is an integral part of adequate resource management and it is essential in achieving other multiple-use benefits. Access, environmental, and economic problems expand with increase in slope. Managers must evaluate different harvesting and site protection alternatives to determine which method — if any — is both economically feasible and environmentally sound.

In a study to define the multiple-use responses of a typical southwestern mixed-conifer watershed, the Forest Service has considered several possible harvest treatments for the South Thomas Creek experimental watershed on the Apache-Sitgreaves National Forest in east-central Arizona (Brown 1976). Water yield response will be tested by cutting marked trees on small areas at 20-year intervals over a 120-year rotation. Subareas of the watershed, defined as Land Response Units (LRU) and identified on the basis

[1]*Associate Systems Analyst, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, Colo., in cooperation with Colorado State University.*

of tree species, soil type, slope, and aspect, are shown in figure 1. Cutting methods are group selection, shelterwood, and individual tree selection. Each LRU has a particular treatment which will result in different harvest volumes for the initial entry:

Land Response Unit (LRU)	Area	Basal area harvested[3]	Harvest gross volume[4]
	Acres	*Percent*	*Mbf*
1	36	40.5	171.7
2	77	28.7	499.6
3	233	22.3	1497.4
4	159	29.4	1179.9
5	55	23.4	181.5
Total	560[2]	—	3530.1

LRU's 1, 2, and 5a are the steep slope areas which make up 20% of total area and 19% of harvest volume.

Topography is a mix of gentle and steep slopes ranging upward to 55%. Some combination of tractor skidding and cable yarding will be required to harvest trees that are marked for cutting without special regard for harvesting convenience. Several combinations of access roads and associated skidding and skyline yarding areas were analyzed to determine the least costly means of treating the watershed within given prescriptions and environmental constraints. The analytical method employed is a composite of appraisal techniques now used in other areas by the National Forest System. Although specific costs shown in this Note cannot be directly applied elsewhere, the concept of systematic analysis should be applicable elsewhere.

Objective

The objective of this analysis was to compare estimated costs of several alternative yarding and skidding combinations along with associated access roads for the South Thomas Creek watershed. Numerous alternative logging and road systems could be developed for logging this watershed, but six alternative systems were identified for further study after initial screening for both environmental and economic effects.

[2]*An additional 2 acres of meadow on the upper watershed are to be protected from all treatment activity.*

[3]*Personal communication from G. J. Gottfried, Research Forester, Rocky Mtn. For. and Range Exp. Sta., Tempe, Arizona, 1975.*

[4]*From Statistical Analysis of Timber Sale, South Thomas Creek. Southwestern Region, USDA Forest Service, 1975.*

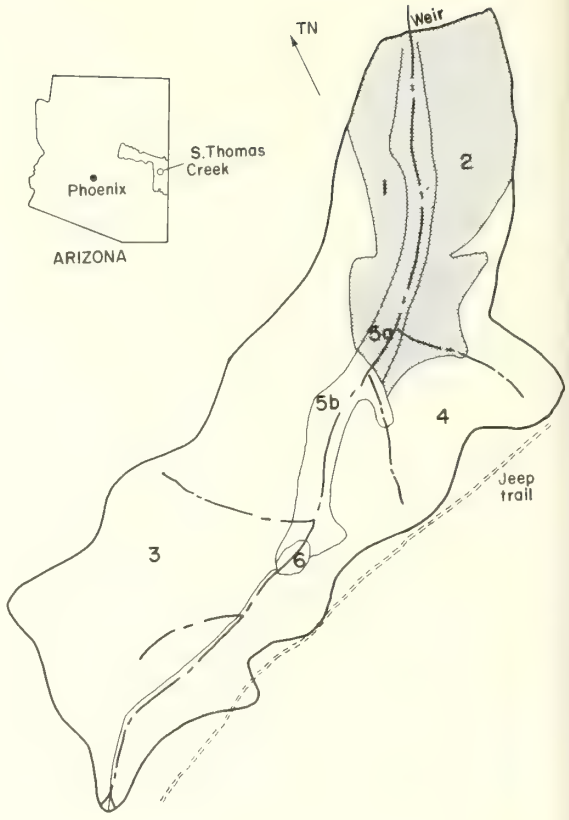


Figure 1.—South Fork, Thomas Creek Watershed Land Response Units (LRU). Shaded section is approximate steep slope area.

Harvest Systems Design

Slope Class Analysis and Road Placement

Inspection of the Thomas Creek topographic map showed general areas of steep and level ground. However, more definitive information was needed on location and extent of areas by percent slope class to locate roads and to designate areas suitable for tractor skidding and skyline yarding.

To satisfy this additional data need, three slope classes were defined on South Thomas Creek: slopes less than 40%; 40% to 50%; and 50% and greater. Each 25-ft contour interval was marked on an overlay according to its slope class. Areas whose slopes were between 40% and 50% and over 50% were interspersed. No large areas fell into either of the two steepest slope classes. Moreover, any part of the watershed designated for cable yarding would necessarily include some areas where slopes are less than 40%.

All South Thomas Creek access roads could be linked to existing haul roads built for an adjacent

commercial timber sale. No special problems in road placement were encountered on the flat areas except a 2-acre meadow in the upper part of the watershed that was to be protected from all treatment activity.

Access roads for cable yarding on steep ground should be on benches or breakpoints between steep and relatively flat ground whenever permitted by topography. No flat benches occur in the South Thomas Creek cable logging area, so roads were planned to be on the terrain breakpoint between steep ground and the ridgetop. Midslope roads were designed to follow the least steep slope available but, unavoidably, some areas with over 50% slope were crossed. The location of a road near the creek bottom was high enough above the creek to satisfy National Forest System sedimentation guidelines. Branch roads for the flat ground were also planned.

All alternative road locations were divided into segments for further analysis. Each distinct road segment was identified by a letter and number denoting branch and segment, respectively.

Road segments required for each alternative are shown in table 1. The "A" branch road segments on flat ground are common to all alternatives, as well as some of the "B" and "C" segments. With these road locations, six alternative skidding/yarding combinations appeared to be technically feasible:[5]

A Cable yard from the creek bottom up to the ridgetop roads (B5, B6, D3, D4). Tractor skid extreme upper parts of each ridge down to the roads (B5, B6, D1, D2, D3, D4).

B,C Cable yard both slopes from the creek bottom up to the roads (B5, B7, D3, D4). Tractor skid down to midslope road (B7) on

[5]*There are 31 combinations possible using 1 or more of the listed roads. And some combinations of road locations have more than one skidding-yarding arrangement. For example, a running skyline interlock yarder could yard both uphill and downhill from a midslope road. This option was not actively considered here because of the high yarder cost and convex topography above the probable location of the midslope road.*

Table 1. Estimated road costs for different treatment alternatives

Road segment	Treatment alternatives and initial road segment cost[1] A	B,C	D	E	F	Segment length	Subsequent reopening, maintenance, closing cost	Road standard
	Dollars					*Ft*	*Dollars*	
A1	497	497	497	497	497	1,360	497	Grade only
A2	746	746	746	746	746	2,040	746	Grade only
A3	1,258	1,258	1,258	1,258	1,258	3,440	1,258	Grade only
B1	1,228	1,228	1,228	1,228	1,228	3,360	1,228	Grade only
B2	293	293	293	293	293	800	293	Grade only
B4	748	748	748	748	748	2,040	748	Grade only
B5	892	892	892	892	892	2,440	892	Grade only
B6	826	—	—	—	—	2,080	826	Grade only
B7	—	14,547	14,547	14,547	14,547	2,640	1,495	Grade, drain, culverts, surfacing
C1	2,400	2,400	2,400	2,400	2,400	2,000	680	Grade, drain, culvert
C2	351	351	351	351	351	960	351	Grade only
C3	2,683	2,683	2,683	2,683	2,683	2,440	891	Grade first 1,200 ft; remainder grade, drain, culverts
C4	—	—	21,696	—	21,696	3,960	2,157	Grade, drain, culverts, surfacing
C5	702	702	702	702	702	1,920	702	Grade only
C6	—	—	220	—	220	600	220	Grade only
D1	238	238	—	238	—	700	238	Grade only
D2	307	307	—	307	—	840	307	Grade only
D3	276	276	—	276	—	800	276	Grade only
D4	3,650	3,650	—	3,650	—	2,800	1,234	Grade, drain, culverts
E1	—	—	—	22,863	22,863	4,080	2,170	Grade, drain, culverts, surfacing
Total road costs	17,095	30,816	48,261	53,679	71,124			

[1]*Includes closure.*

SE-facing upper slope and down to ridge road (D3, D4) on extreme upper NW-facing slope. (Two different size yarders were considered in this alternative.)

D Cable yard up to each midslope road (B5, B7, C3, C4) from the creek bottom. Tractor skid each slope's upper area down to the road (B5, B7, C3, C4).

E Cable yard the upper part of the NW-facing slope to the ridge road (D3, D4). Tractor skid as high as practicable on NW-facing slope to creek bottom road (E1). Tractor skid entire SE-facing slope, the upper part down to "midslope" road (B5, B7), the lower part down to creek bottom road (E1).

F Cable yard the lower part of the NW-facing slope from the midslope road to the creek bottom road (E1). Tractor skid upper part of NW-facing slope down to the midslope road (C3, C4). Tractor skid entire SE-facing slope, the upper part down to the "midslope" road (B5, B7) and the lower part down to the creek bottom road (E1).

Cable Yarding and Tractor Skidding Areas

Once the road network for each alternative was identified on individual overlays, yarding areas were defined. Logs can be decked by conventional wheeled skidders on approximately 80% of the area, but cable yarding should be used for the remaining steep slopes. Cable yarding boundaries depended on access road location and the amount of continuous terrain with slope greater than 40%. Approximate yarder setting and cable corridor locations were based on an assumed total setting width of 150 ft. For yarder locations on the southeast-facing slope, tailspars could easily be located on the opposite slope to gain additional deflection and load capacity. Where settings on the northwest-facing slope were too long for tailspars on the opposite slope, tailspars were planned for the same slope as the yarder. No anchor problems were anticipated, since there are numerous large, deeply rooted ponderosa pines and no major windfall areas on the steep slopes. Landing and log deck locations were adequate in most areas; in tight areas a grapple skidder could swing logs to a more convenient deck location.

All ground not covered by cable yarding would be tractor skidded. Each planned access road would have one or more adjacent log decks. On flat areas, skidders would travel equal distances to roadside decks from both sides of the road. On steeper areas, loaded skidders would travel downhill to the road wherever possible. Estimated average skid distances, stratified for uphill and downhill directions, were computed for each alternative on the basis of overlay map areas.

Cut Timber Volume For Yarding And Skidding Areas

Feasible yarding and skidding area boundaries for each alternative did not coincide with the LRU boundaries, so harvest volumes, available by LRU, were apportioned between the cable yarding area and the uphill and downhill tractor skidding areas. These areas are slightly different for each alternative, resulting in different log volumes to be handled in each case by cable yarding and tractor skidding (table 2).

Appraisal

Road Costs

All road location data were evaluated by personnel of the Apache-Sitgreaves National Forest to estimate costs for each possible road segment (table 1). Their suggested cost estimates were based on the road standards necessary to conform with resource protection requirements developed in an environmental analysis of the proposed watershed treatments.

Road segment costs were estimated for three road standards: graded only; graded and drained with culverts; and graded, drained with culverts, and surfaced. Road closing costs were assumed to be the same for each road standard. Since cost increases as side slope increases, the cost for each road segment was affected by how much of its length fell into each of the three slope classes. For example, road segment A-1, which required grading only, had a total length of 1,360 ft, all on slopes less than 40%. Its total estimated cost was $497 including closure after watershed treatment[6]. However, road segment B-7, requiring grading, drainage, culverts, and surfacing, had a length of 1,400 ft on slopes less than 40%, a length of 440 ft on slopes between 40% and 50%, and a length of 800 ft on slopes greater than 50%. This resulted in a total estimated cost of $14,547, including closure. Total road costs for each alternative were determined by adding costs for all road segments included in that alternative (table 1).

Road costs are large factors in the total cost for roads, yarding, and skidding (table 2). In Alterna-

[6]*All cost estimates, current for late 1975, were estimated to the nearest dollar; however, accuracy to the nearest dollar is not implied.*

Table 2. Alternative costs for initial entry

Alternative[1]	Cable yarding area	Gross volume[2]		Total cost				Cost per net M bd ft[3]			
		Cable yarding	Tractor skidding	Cable yarding	Tractor skidding	Skidding and yarding	Road	Total	Cable yarding	Tractor skidding	Skidding and yarding	Road	Total
	Acres	*M bd ft*		*Dollars*					*Dollars*				
A	125	659 160	2870 940	36 455	15 675	52 130	17 095	69 225	73.74	7.28	19.69	6.46	26.15
B	115	610 103	2919 997	32 887	16 031	48 918	30 816	79 734	71 87	7.32	18.48	11.64	30.12
C	115	610 103	2919 997	24 958	16 031	40 989	30 816	71 805	54.54	7.32	15.48	11.64	27.12
D	88	373 450	3156 649	18 506	17 875	36 381	48 261	84 642	66 07	7.55	13.74	18.23	31.97
E	59	420 716	3109 384	16 352	17 350	33 702	53 679	87 381	51 82	7 44	12.73	20.27	33.00
F	50	238 827	3291 272	10 873	18 834	29 707	71 124	100 831	60 70	7.63	11 22	26 86	38 08

[1] *Alternatives A and B assume a yarder with a capital investment of $170,000. The remaining alternatives assume a yarder with a capital investment of $100,000*

[2] *Computed from data in R 3 Thomas Creek sale analysis printout*

[3] *Computed using 25% combined woods and mill defect*

tives C, D, and F, total tractor skidding cost remains about the same, total cable yarding cost decreases, yet total cost increases significantly because of the road cost required to support added tractor skidding areas. For example, going from alternative D to F switches 38 net acres from cable logging to tractor logging, and increases road costs from $48,261 to $71,124.

Also, alternative C specified one road on the southeast-facing midslope built to the minimum standard required to satisfy soil protection guidelines. Note that the total cost difference between alternatives A and C is only $0.97 per net thousand bd ft. If road costs for alternative C could be reduced from $30,816 to $28, 245, the cost per net thousand bd ft would be equal for alternatives A and C.

Cable Yarding Costs

Yarding on the South Thomas Creek watershed will require a yarder with a reach of either 1,500 ft or 900 ft, depending on which access road alternative is chosen. Specifications were reviewed for several yarders in both size classes. One typical 1,500-ft-reach yarder used in a live skyline configuration cost approximately $170,000 in late 1975. A typical 900-ft-reach yarder also used in a live skyline configuration cost about $100,000 in late 1975. In the following discussion these are termed "intermediate yarder" and "small yarder", respectively.

Load carrying capability for each yarder was determined by use of a load path analysis computer program,[7] with the following specifications assumed for each yarder.

	Intermediate yarder	Small yarder
Skyline diameter, in	1.00	0.75
Skyline length on drum, ft	1,930	1,100
Mainline diameter, in	0.75	0.56
Mainline length on drum, ft	1,870	1,800
Tower height, ft	48	42
Tailspar height, ft	30	30
Carriage weight, lbs	500	500

This analysis estimates payload weight that can be carried on each turn, a figure important in the appraisal process to estimate bd ft volume of logs carried per turn.

[7] *U.S. Dep. Agric., For. Serv., Rocky Mt. Reg. Unpublished documentation for computer program, SKYSL. n.d. This program is based on work done by Ward Carson and others at the Pacific Northwest Forest and Range Exp. Stn.*

Yarding distances are longest on both sides of the lower end of the watershed. While the skyline may be anchored at a point considerably more than 1,000 ft from the yarder on these few settings, the carriage will seldom, if ever, be more than 1,000 ft from the yarder. A 3/4-in mainline should not be too heavy for manual slackpulling; however, if a lighter 9/16-in mainline were required, payload will necessarily be smaller on any given setting.

Current Forest Service timber appraisal methods estimate cable yarding costs on both a total and a per-thousand-bd-ft basis (USDA Forest Service 1975). Required input data include number of logs per thousand bd ft, number of logs per acre, average rigging time per setting, and the machine rate of the yarder in dollars per hour. The appraisal procedure estimates production per hour, total time required for all settings, cost of yarding, cost of constructing landings, and cost of crew transport. Total costs are shown in table 2.

Tractor Skidding Costs

The Appraisal Handbook for the Southwestern Region provides data for estimating costs of tractor skidding (USDA Forest Service 1972). Total tractor skidding area is stratified into subareas based on uphill or downhill skidding, percent sideslope, average log volume, and average skid distance. The appropriate appraisal tables are entered with these average figures for each subarea, and cost factors are extracted to modify the regional average cost figures. Finally, an overall average cost per thousand bd ft for the whole skidding area is found by weighting cost for each subarea according to its log volume.

Costs derived by this method are shown in table 2. Tractor skidding volume increases from alternative A to F, except for alternative E. For alternative E, skid volume decreases, lowering total skidding cost proportionately. For tractor skidding only, alternatives B and C are identical.

Total Costs

To compute total costs for the entire watershed, cable yarding and tractor skidding costs were weighted by volume cable-yarded or tractor-skidded. Cruise data suggested that a 25% defect factor was average for trees on the harvest site. Therefore, costs per thousand bd ft gross scale for roads, cable yarding, and tractor skidding were totalled and converted to a net scale basis, using the 25% defect factor (table 2).

Alternatives A and B use a mobile intermediate yarder for settings with skyline spans to 1,500 ft. This yarder would require access roads either on both ridges (alternative A), or on one ridge and a midslope (alternative B). Low road costs for alternative A more than offset the higher capital and operating costs of this yarder, which results in the least cost yarding system for this analysis (table 2).

The last four alternatives employ a smaller yarder for settings with skyline spans to 900 ft. Alternative C has the same road system as alternative B but uses the smaller yarder, the only instance where this happens. By judicious use and location of tailspars, the smaller yarder can just barely satisfy yarding distance requirements with the road locations of alternatives B and C. Economically, alternative C is the opposite of alternative A, because in alternative C higher road costs are offset by lower capital and operating costs of the smaller yarder.

Discounted Alternative Costs[8]

A 120-year rotation with a stand treatment at 20-year intervals requires seven entries, including the initial one. An analysis using current values of future costs suggests which strategy is least expensive from an economic viewpoint — to build higher cost midslope roads and spend less for a smaller yarder at each entry, or to build lower cost roads on the ridges and spend more for a larger yarder at each entry. In this analysis it was assumed that road costs are a capital investment extending over the entire rotation period and that logging costs would be equal for each entry. Road costs for each entry after the first were assumed to be for road grading only, regardless of original road standard, and for subsequent closure.

Some environmental aspects, such as prevention of sedimentation, are built into significantly higher road costs for increasing sideslopes. This analysis is primarily economic, however, so other environmental features, such as esthetics, which in many cases would have importance equal to or greater than the treatment cost, are not quantified.

Discounted costs for all alternatives are shown in table 3, but only alternatives A and C are discussed further because they have the two lowest discounted costs.

At a 6% discount rate, alternative C costs less than A over a 120-year rotation. However, a high-

[8]*John Sessions, USDA Forest Service Logging Systems Training Program, Corvallis, Oregon suggested the analysis of discounted alternative costs.*

Table 3. Estimated cash flow for one rotation discounted to present value at three interest rates[1]

Alternative (1)	Cable yarding cost: Each entry[2] (2)	Cable yarding cost: Present value of total rotation entry, 6% (3)	Tractor skidding cost: Each entry[2] (4)	Tractor skidding cost: Present value, 6% (5)	Road cost: Initial cost (6)	Road cost: Each reentry[3] (7)	Road cost: Present value, 6% (8)	Total cost, present value, 6%[4] (9)	Total cost, present value, 10% (10)	Total cost, present value, 14% (11)
					Dollars					
A	36,455	52,957	15,675	22,770	17,095	11,167	5,055	97,877	80,275	74,192
B	32,887	47,773	16,031	23,287	30,816	11,836	5,358	107,234	90,340	84,501
C	24,958	36,255	16,031	23,287	30,816	11,836	5,358	95,716	81,027	75,950
D	18,506	26,883	17,875	25,966	48,261	12,158	5,503	106,613	93,116	88,451
E	16,352	23,754	17,350	25,203	53,679	14,006	6,340	108,976	95,710	91,125
F	10,873	15,795	18,834	27,359	71,124	14,328	6,486	120,764	108,519	104,286

[1]*The factors for this analysis were obtained from Table 2 in Lundgren (1971). The interest rate was applied for 20 years, 40 years, etc. up to one rotation of 120 years.*
[2]*Assume that identical cable yarding and tractor skidding costs will be incurred at each 20-year entry.*
[3]*Includes regrading and closing cost at each 20-year entry.*
[4]*Figures in column 9 are the sum of figures in columns 3, 5, 6, and 8 for each alternative.*

er discount rate is probably more realistic. In table 3, discounted total costs at either a 10% or 14% rate show alternative A costs less than C, in contrast to the result at the 6% rate. In any case, the differences are slight for the two alternatives over the 120-year period.

Since present assumptions about logging technology and associated road requirements are not likely to remain valid for much more than 20 years, the relative ranking of alternatives A and C for a 20-year period should be considered. This interval corresponds to the initial treatment plus one reentry. Figure 2 shows the present value of cost differences between alternatives A and C for a range of discount interest rates and for a 20-, 40-, and 120-year time period.

A curve value in figure 2 is positive when alternative A costs more than C at the end of the time period for a selected interest rate. When a curve value is negative at a given interest rate, alternative A costs less than C at the end of the time period. For example, at an 8% discount rate, alternative A costs $290 more than C for 120 years, but $334 less than C when the time period is limited to 20 years.

Obviously, interest rate and time period assumptions can have a great effect on discounted cost analyses. On the South Thomas Creek watershed, an interest rate choice of about 9% or greater will always result in alternative A costing less than C for any time period less than 120 years.

Summary and Discussion

Opportunities for combined tractor and cable logging will likely increase in the central and southern Rocky Mountains. The purpose of this case study was to bring together and apply current appraisal techniques to determine the combined cost of tractor skidding and cable yarding on a specific site.

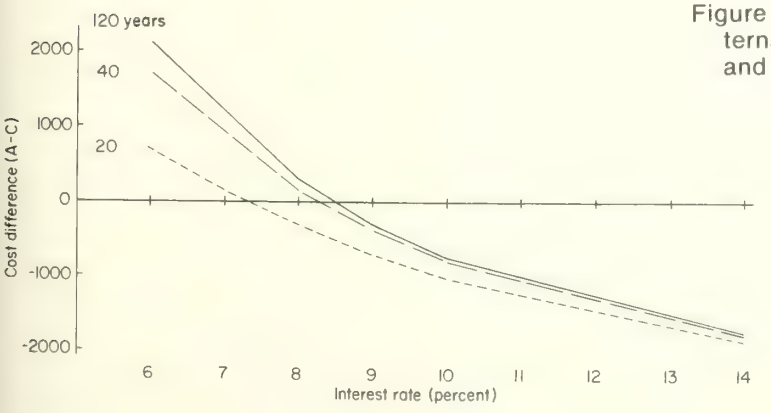


Figure 2.—Discounted cost difference between alternatives A and C for a range of interest rates and time periods.

An analysis was made of the topography on South Thomas Creek to classify areas by percent slope. This information was used to determine the location of suitable roads and to determine which areas of the watershed could be tractor skidded and which areas could be cable yarded only.

Six technically feasible combinations of roads, cable yarding, and tractor skidding were examined. Two combinations, alternatives A and C, cost significantly less. For the initial treatment entry, alternative A costs slightly less than alternative C, while for seven treatment entries during a 120-year rotation, alternative C costs slightly less than alternative A, using a 6% discount interest rate. However, with interest rates of about 9% or greater, alternative A costs less than C for any time period up to 120 years.

This analysis is primarily economic rather than environmental but does reflect increased soil protection costs in terms of road standards. Qualitative effects such as esthetics are not included, and even though economic ranking includes some environmental considerations, it is recognized that other factors defined in Forest Service Environmental Analysis Reports may take precedence when deciding between alternative skidding or yarding plans. Improved technology will likely make the technical assumptions of this analysis obsolete before the end of the 120-year rotation, possibly before the end of the first 20-year interval. Thus, projections of long-term costs are dependable only as long as they continue to represent relative costs between alternatives.

This analysis demonstrates cost tradeoffs between yarding and skidding costs and road costs. Such analysis may be useful in evaluating broader concepts. For example, the idea has recently developed that smaller, less expensive yarders are needed to harvest small timber on steep slopes in the Rocky Mountains. However, it is apparent from this case study that if using smaller yarders always implies a short reach, increased access road costs could offset capital savings on the yarder. This implies that while there may be a place in the central and southern Rocky Mountains for short-reach yarders, there may also be a place for larger yarders with a reach from 1,500 to 3,000 ft, where the reduced cost of low density access roads would offset the higher capital and operating costs of larger yarders.

One possible way to reduce access roads is to combine high flotation tracked skidders with long reach cable systems. For example, a tracked skidder with a low center of gravity and low ground pressure has recently been used in western Canada on slopes up to 50% (Overend 1975). Such a skidder could be used to deck logs from steep slopes at a concentration point remote from the main access road. A long-reach cable yarder could then swing yard the logs to the road with efficiency because few moves of the skyline would be required (Mason 1976). An analysis similar to this could be used to estimate the comparable costs of this alternative.

It is significant that this small (562-acre) watershed had at least six feasible alternative road, skidding, and yarding combinations out of the many that could be considered. Larger harvest areas conceivably might have several times this number of alternative combinations of access roads, tractor skidding and cable yarding areas. The variety of these factors in future timber sales could provide hundreds of possible case analysis situations analogous to the one described here.

Extensive analysis of many combinations of cable yarding, tractor skidding, and road location using manual computation methods would be prohibitively expensive. Using such methods, this manual analysis, covering only six alternatives, required an estimated 25 man-days over a 6-week period. A computerized system for harvest alternatives analysis would allow much more comprehensive presale planning without greatly increasing the planning effort but would require a large initial investment in computer program development.

Literature Cited

Brown, Thomas C. 1976. Alternatives analysis for multiple use management: A case study. USDA For. Serv. Res. Pap. RM-176, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Lundgren, Allen L. 1971. Tables of compound-discount interest rate multipliers for evaluating forestry investments. USDA For. Serv., Res. Pap. NC-51. 142 p. North Central For. Exp. Stn., St. Paul, Minn.

Mason, Duane C. 1976. LGP skidder "flown" across to help log on sensitive watershed terrain. For Ind. 103(12):40-1.

Overend, Miles. 1975. FMC 200 BG helps tackle steep slopes of Kootenays. Pulp and Pap. Mag. Can. 76(10):61-3.

U.S. Department of Agriculture, Forest Service. 1972. Timber appraisal handbook, FSH 2409.22 R-3 [amended]. U.S. Dep. Agric., For. Serv., Reg. Three. Albuquerque, N.M.

U.S. Department of Agriculture, Forest Service. 1975. Addenda to timber appraisal — skyline yarding. 7 p. U.S. Dep. Agric., For. Serv., Reg. One, Clearwater Nat. For.

1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-342

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Some Characteristics Of Arizona's Mixed Conifer Forest Floor

Peter F. Ffolliott, Frederic R. Larson, and Ronald E. Thill[1]

SEP 9 1977

Timber basal area was the only stand or site variable tested that was significantly related to forest floor depth and weight. Frequency distributions of forest floor depths were developed for use as a management tool when depths affecting wildland products are defined.

Keywords: Forest litter, mixed conifer forest type.

The forest floor, defined as the accumulation of dead organic matter above mineral soil, has an important influence on tree regeneration, herbage production, and the hydrologic characteristics of a site. In addition, it is an important forest fuel component. Generally, three layers are distinguished: the **L** layer, unaltered organic matter; the **F** layer, partly decomposed matter; and the **H** layer, well decomposed matter.

Characteristics of the forest floor under Arizona's ponderosa pine (*Pinus ponderosa*) forests have been documented in previous studies (Ffolliott et al. 1968, 1976). The objectives of this Note were to: (1) describe the depth and weight characteristics of Arizona's uncut mixed conifer forest floor; (2) determine whether or not the amount of forest floor can be estimated from readily obtained stand and site variables; and (3) compare the characteristics of the forest floor developed under ponderosa pine and mixed conifer forests.

[1]*Ffolliott is Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Larson is Silviculturist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Thill is Research Assistant, School of Renewable Natural Resources, University of Arizona, Tucson.*

Study Area

The study area encompassed three watersheds (North and South Fork of Thomas Creek and West Fork of Willow Creek) totaling approximately 1,275 acres within the Black River Barometer watershed in east-central Arizona (Rich and Thompson 1974). Seven coniferous and one deciduous species occur in a wide variety of intermixtures on the area: Engelmann spruce (*Picea engelmanii*), blue spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), white fir (*Abies concolor*), corkbark fir (*Abies lasiocarpa* var. *arizonica*), ponderosa pine, southwestern white pine (*Pinus strobiformis*), and quaking aspen (*Populus tremuloides*).

Current gross sawtimber volume averages 21,700 bd ft per acre. Annual precipitation averages 28 in; soils are developed from basalt; elevations range from 8,400 ft to 9,300 ft.

Methods

Depth of individual forest floor layers was measured at 359 randomly located sample plots on 3 watersheds. Only coniferous needles and aspen leaves in various stages of decomposition were considered. Depth was measured without compressing the layers at four sample points within 2 ft of the plot center, one in each "quadrant". An average of the four depth measurements, recorded to the nearest 0.1 in was used.

The weight of the individual forest floor layers was obtained from 1-ft² samples taken in one quadrant at every fifth sample plot; 73 samples were obtained. These samples were brought into the laboratory to determine oven-dry weights. Corresponding depth measurements were taken at four sides of the ft² samples.

Data necessary to synthesize stand and site variables were obtained from timber inventory data taken at each sample plot. Basal area density was estimated by point sampling with an angle gage corresponding to a basal area factor of 25. Potential insolation, expressed in terms of gram-calories per cm², was determined from slope and aspect measurements (Frank and Lee 1966).

Results

Means and standard errors for depth and weight are presented in table 1. Mixed conifer forest floors generally weigh more than ponderosa pine for comparable depths. Greater **F** and **H** layer weights in the mixed conifer forest are the apparent reason for the difference.

Table 1.—Means and standard errors for depth and weight

Forest floor layers	Depth		Weight	
	Mean	$S_{\bar{x}}$	Mean	$S_{\bar{x}}$
	Inches		*Tons Per Acre*	
L	0.2	0.01	0.4	0.05
F	.7	.02	10.3	.73
H	.7	.02	10.4	1.14
Total Floor	1.6	.04	21.1	1.34

Frequency distributions of forest floor depths by individual layers are illustrated in figure 1. Forest floor accumulations tend to be deeper under mixed conifer than ponderosa pine forests (Ffolliott et al. 1968, 1976).

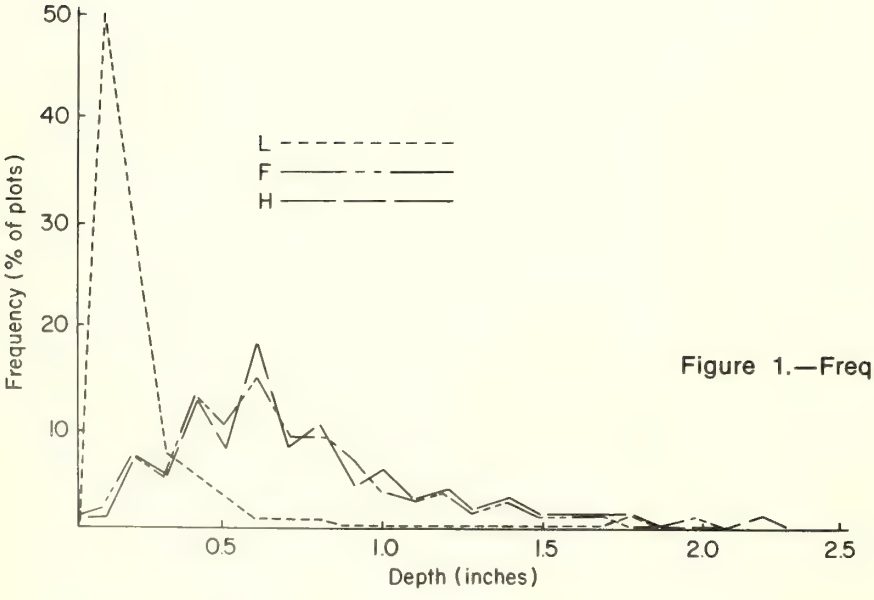


Figure 1.—Frequency distribution of forest floor depths by layers.

If specific depths of forest floor can be defined as affecting tree regeneration, herbage production, site hydrology, or forest fuels, these frequency distributions can be used to estimate the portion of Arizona's uncut mixed conifer forests that is characterized by these amounts.

Theoretically, crown closure and temperature can affect the depth of forest floor (Kittredge 1948, Lutz and Chandler 1951). We therefore attempted to relate the individual layer and total floor depths and weights to crown closure and temperature by empirical regression analysis. Crown closure can be estimated by basal area[2], and temperature is indexed by potential insolation.

Basal area was the only independent variable that showed significant regressions for forest floor depth and weight, excluding the **L** layer. The prediction equations, when basal area (X) is expressed in ft² per acre, are:

Forest floor depth *Inches*	Forest floor weight *Tons per acre*
$Y_T = 1.20 + 0.0023X$ $r = 0.28$	$Y_T = 9.20 + 0.065X$ $r = 0.46$
$Y_H = 0.52 + 0.00091X$ $r = 0.23$	$Y_H = 2.30 + 0.044X$ $r = 0.36$
$Y_F = 0.48 + 0.0015X$ $r = 0.25$	$Y_F = 6.40 + 0.022X$ $r = 0.28$
Y_L (Not significant)	Y_L (Not significant)

With the exception of the **L** layer, the equations for predicting forest floor depth and weight from timber basal area were similar to those reported for ponderosa pine forests (Ffolliott et al. 1968, 1976).

While they may have some significance, the forest floor-basal area relationships did not have high correlation. According to Brown (1966), predictions of the amount of forest floor from stand site variables are most dependable in stands with uniform structure. Unfortunately, uniformity is not the norm in Arizona's mixed conifer forests.

The relation of weights of forest floor layers to depths is given in figure 2. The relationship $Y = bX$, as determined from the average of the ratios of weight and depth (Natrella 1965), was used to develop these functions. As under ponderosa pine forests, the **H** layer is denser than the **L** and **F** layers.

[2]*An unpublished study, untitled, on file at the School of Renewable Natural Resources, University of Arizona, Tucson, has shown percent of overhead crown closure in a mixed conifer forest stand in east-central Arizona to be correlated with basal area density estimated by point sampling with a basal area factor of 25.*

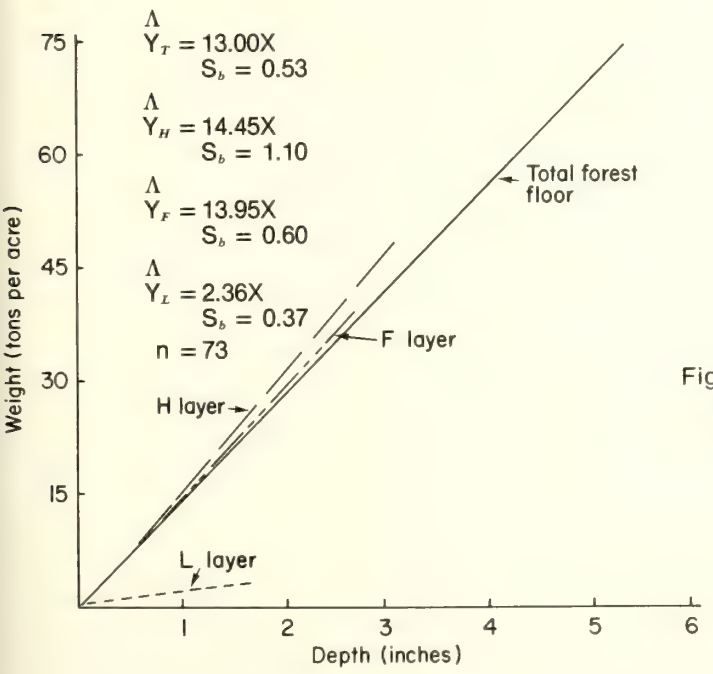


Figure 2.—Relationship between forest floor weight and depth. Lengths of regression lines indicate range of data.

Summary

1. The mean depth and weight of the forest floor in Arizona's uncut mixed conifer forests were 1.6 in and 13.0 tons per acre, respectively, with the greatest accumulations in the F and H layers.

2. Frequency distributions of forest floor depths were developed for use when depths affecting wildland products are defined.

3. Timber basal area was the only tested stand or site variable significantly related to individual layer (with the exception of the L layer) or total forest floor amounts. Although the correlations were low, the regressions may prove helpful in describing forest floor characteristics under Arizona's mixed conifer forests.

Literature Cited

Brown, James K. 1966. Forest floor fuels in red and jack pine stands. USDA For. Serv. Res. Note NC-9, 3 p. North Central For. Exp. Stn., St. Paul, Minn.

Ffolliott, Peter F., Warren P. Clary and James R. Davis. 1968. Some characteristics of the forest floor under ponderosa pine in Arizona. USDA For. Serv. Res. Note RM-127, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ffolliott, Peter F., Warren P. Clary, and Malchus B. Baker, Jr. 1976. Characteristics of the forest floor on sandstone and alluvial soils in Arizona's ponderosa pine type. USDA For. Serv. Res. Note RM-308, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Frank, Ernest C., and Richard Lee. 1966. Potential solar beam irradiation on slopes: Tables for 30° to 50° latitude, USDA For. Serv. Res. Pap. RM-18, 116 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Kittredge, Joseph. 1948. Forest influences. 394 p. McGraw-Hill Book Co., Inc., New York.

Lutz, Harold J. and Robert F. Chandler, Jr. 1951. Forest soils. 514 p. John Wiley & Sons, Inc., New York.

Natrella, Mary Gibbons. 1965. Experimental statistics. Nat. Bur. of Stand. Handb. 91, 360 p.

Rich, Lowell R. and J. R. Thompson. 1974. Watershed management in Arizona's mixed conifer forests: The status of our knowledge. USDA For. Serv. Res. Pap. RM-130, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Fort Collins

1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-343

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The Effects of Endomycorrhizae on Growth of Rabbitbrush, Fourwing Saltbush, and Corn in Coal Mine Spoil Material[1]

D. L. Lindsey, W. A. Cress[2], and E. F. Aldon[3]

COLORADO UNIVERSITY LIBRARY
SEP 8 1977

The influence of vesicular arbuscular endomycorrhizae formed by *Glomus fasciculatus* on the survival and growth of rubber rabbitbrush, fourwing saltbush, and corn on coal mine spoil material was studied. *G. fasciculatus* endomycorrhizae increased the survival and growth of rabbitbrush but had no effect on fourwing saltbush or corn.

Keywords: Endomycorrhizae, *Chrysothamnus nauseosus*, *Atriplex canescens*, mine spoil reclamation.

Introduction

There has been only limited research on the mycorrhizal associations of plants colonizing strip-mined land and mining waste materials; however, the ecological importance of these associations has been suggested by several researchers (Aldon and Springfield 1975, Daft and Nicolson 1974, Daft, Hacskaylo and Nicolson 1975, Marx 1975, Schramm 1966). Schramm (1966) concluded that successful colonists on waste material were either nitrogen-fixing plants or ectomycorrhizal trees; however, endotrophic mycorrhiza were present, though rare, on these wastes. Marx (1975) has established that *Pisolithus* spp. ectomycorrhizae are instrumental in establishment and maintenance of pines on strip-mined spoils. Daft et al. (1975) found that grasses and other herbaceous plants colonizing the anthracite and bituminous coal spoils in Pennsylvania and bituminous coal spoils in Scotland generally were infected with endomycorrhizal fungi. These workers demonstrated that an endomycorrhizal fungus, *Gigaspora gigantea* (Nicol. and Gerd.) Gerdemann and Trappe, comb. nov., from Pennsylvania coal spoil stimulated the growth of corn in sand culture. They also found that *Glomus macrocarpus* var. *geosporus* (Nicol. and Gerd.) Gerdemann and Trappe, comb. nov., from coal spoil in Scotland stimulated the growth of

[1]*The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a USDA Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. Journal Series 613, Agricultural Experiment Station, New Mexico State University, Las Cruces. This research was supported in part by USDA Forest Service, Grant No. 16-415-CA.*

[2]*Department of Botany and Entomology, New Mexico State University, Las Cruces.*

[3]*Principal hydrologist, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque, in cooperation with the University of New Mexico. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

wild strawberry growing in pots containing sterilized spoil material. Aldon (1975) found that endomycorrhizae increased survival and growth of fourwing saltbush on strip-mined coal spoils in New Mexico.

The investigations described herein were undertaken to determine the effect of endomycorrhizae on the survival and growth of plants on coal spoil material collected from the McKinley coal strip-mine in northwestern New Mexico.

Materials and Methods

Growth Medium. Spoil material was collected in July 1975 from a recently graded spoil bank on the McKinley coal strip-mine near Gallup, New Mexico. Spoil material to the depth of 15 cm was collected and thoroughly mixed. Approximately half of the spoil material was autoclaved for 8 hrs at 121° C, and then spread out on a greenhouse bench to aerate for 7 days. The nonsterilized and sterilized spoil material were stored in 76-l metal containers in the greenhouse. The spoil material possessed the following characteristics: pH (saturated paste), 6.7; electrical conductivity, 4.5 x 10^3 mmhos; Ca, 32.6 meq/l; Mg, 18.8 meq/l; Na, 19.1 meq/l; sodium adsorption ratio, 3.8; extractable K, 0.33 meq/100g; extractable NO_3, 320 ppm; extractable P ($NaHCO_3$), 0.52 ppm; and organic matter, 6.7%.

Experimental Plants. Three plant species were selected: corn, *Zea mays* L. (Funk's 4384A), rubber rabbitbrush, *Chrysothamnus nauseosus* (Pall.) Britton, and fourwing saltbush, *Atriplex canescens* (Pursh.) Nutt. The latter two species are shrubs native to the area surrounding the McKinley mine. Seeds of these plants were placed on the surface of spoil material in ten 20-cm plastic pots containing 1,500 g spoil material and covered with a layer of sterile river sand. After 3 weeks, plants were thinned to one plant/pot. Plants were grown under greenhouse conditions and watered with tap water.

Endomycorrhizal Fungi. The mycorrhizal inoculum was obtained from soil collected around rabbitbrush and fourwing saltbush plants growing on nondisturbed sites near the spoil banks. Chlamydospores of *Glomus fasciculatus* (Thaxter sensu Gerdemann) Gerdemann and Trappe, comb. nov., plus a small number of *Glomus mosseae* (Nicol. and Gerd.) Gerdemann and Trappe, comb. nov., were extracted from 250 cc soil by the wet sieving and decanting method of Gerdemann and Nicolson (1963). Infestation of spoil material with mycorrhizal fungi was accomplished by thoroughly mixing the spoil material in each pot with chlamydospores extracted from 250 cc soil.

To evaluate the effect of the mycoflora other than mycorrhizal fungi on plant growth in spoil material, soil washings (in each case 75 ml of the above soil suspension which passed through a 45μ mesh screen) were added to pots with spoil material.

Growth Measurements. Plant shoots were cut off at the soil line at the termination of the study and heights were measured (base of stem to apical meristem). Shoots were dried at 80° C for 48 hrs and then weighed.

Effects of Phosphorus Fertilization. To determine the effect of phosphorus alone on the growth of the three host plants in nonsterilized spoil material, the plants were grown in pots containing the following amounts of 0-46-0 phosphorus fertilizer: 0 g/pot, 0.3 g/pot and 1.0 g/pot. Rabbitbrush (three replications) was grown for 137 days, fourwing saltbush (five replications) for 137 days, and corn plants (two replications) for 110 days.

Chemical Analysis. The dried plant material from each pot was ground in a Wiley tissue mill with a #40 screen. Tissue samples were digested as reported by Throneberry (1974) and phosphorus content determined spectrophotometrically using a modification of the Murphy and Riley method (1962). Nitrogen content was determined by Winkler's Kjeldahl method as modified by Ma and Zuazaga (1942). Zinc and manganese contents were determined by atomic absorption spectrophotometer.

Determination of Mycorrhizal Condition. The presence of a mycorrhizal association was determined by microscopic examination of stained roots. Roots were cleared and stained with cotton blue (Bevege 1968) and subsequently examined for the presence of coenocytic hyphae, arbuscules and vesicles.

Results

Rabbitbrush. Rabbitbrush plants were grown for 132 days in sterilized and in nonsterilized mine spoil materials receiving the following treatments: control, soil washings and mycorrhizal inoculum. After 132 days, plant growth on sterilized and nonsterilized spoil material was similar (table 1). Endomycorrhizae were established only

Table 1.—Effect of endomycorrhizae on rabbitbrush grown in mine spoil material for 132 days.

Treatment	Mycorrhizal condition	Height	Dry weight	N	P	MN	ZN
		cm	*µg/g*	..... %		.... µg/g ...	
Sterilized spoil material							
Control	—	1.2a[1]	11a	—[2]	—	—	—
Soil washings	—	1.9a	20a	—	—	—	—
Mycorrhizal inoculum	+	6.7b	149b	1.78	0.148	58	327
Nonsterilized spoil material							
Control	—	1.5a	36a	—	—	—	—
Soil washings	—	1.5a	22a	—	—	—	—
Mycorrhizal inoculum	+	5.5b	127b	1.16	0.179	54	180

[1]*Means in the same column followed by the same letter do not differ significantly at 1% level.*
[2]*Insufficient tissue for chemical analysis.*

in those plants growing in spoil material receiving endomycorrhizal fungus inoculum. Coencytic hyphae and vesicles were observed in roots.

Mycorrhizal plants growing in both the sterilized and nonsterilized material had significantly greater dry weights and heights than those plants without endomycorrhizal fungi. Insufficient tissue was obtained from plants in the control and soil washing treatments for N, P, Mn and Zn analysis; therefore, comparisons could not be made between mycorrhizal and nonmycorrhizal plants for these elements. A repeat experiment showed similar results.

Figure 2.—Rabbitbrush seedlings grown in uninoculated, sterile mine spoil material (left) and sterile mycorrhizal spoil (right).

Figure 1.—Effect of inoculating mine spoil material with *G. fasciculatus* on rabbitbrush seedlings. Spoil material from left to right: nonsterile control, nonsterile washings, and nonsterile mycorrhizal.

The mycorrhizal growth response was first observed 10 weeks after plants had emerged. In the first and second experiments, approximately 25% and 60%, respectively, of the nonmycorrhizal plants died after becoming established. In contrast, no mycorrhizal plants died in the first experiment and only one died in the second experiment, after establishment.

G. fasciculatus spores were the predominant ones found in the spoil material surrounding the roots of the mycorrhizal plants at the end of the experiment. The only other type of endomycorrhizal fungal spore observed in this material, and only occasionally, belonged to *G. mosseae.*

Fourwing Saltbush. After 119 days, endomycorrhizal association were not established in any of the plants in this experiment, even in the treatments receiving mycorrhizal inoculum. Microscopic examination of cleared and stained roots revealed no typical mycorrhizal structure or stained coenocytic hyphae. These plants grew very little and the lower leaves had fallen off at harvest. No differences in height or dry weight were noted between treatments. Plant survival was 100% in all treatments. Similar results were obtained when this experiment was repeated.

Corn. After 94 days, little difference was noted in plant growth in the sterilized and nonsterilized spoil material (table 2). Only plants growing in spoil material receiving mycorrhizal inoculum were found to have endomycorrhizae.

There were no differences in height, dry weight or nitrogen and phosphorus content between mycorrhizal plants and plants grown in spoil material receiving soil washings. The mycorrhizal plants were significantly taller and had a greater dry weight than the control plants. No difference in phosphorus content of the control and mycorrhizal plants was found. There was no difference in the nitrogen content of the control and mycorrhizal plants in the sterilized spoil material; however, the control plants in the nonsterilized spoil material contained significantly more nitrogen than the mycorrhizal plants. In a repeat of this experiment similar results were obtained.

Corn plant survival was 100% in all treatments but leaves exhibited typical phosphorus deficiency symptoms 3 weeks after emerging. Senescence of lower leaves occurred after 6 weeks in all treatments, and at the end of the experiment only the terminal three leaves were functioning.

Phosphorus Test. Rabbitbrush plants growing in mine spoil material receiving phosphorus fertilizer were approximately 10 times taller and had 35 times greater dry weight than the control plants (table 3). There was little difference in the height and dry weight of the rabbitbrush plants receiving the two rates of P fertilizer.

Little difference in fourwing saltbush plant height was observed between the plants receiving

Table 2.—Effect of endomycorrhizae on corn grown in mine spoil material for 94 days.

Treatment	Mycorrhizal condition	Height	Dry weight	N	P
		cm	*g*	..... %	
Sterilized spoil material					
Control	—	15.7a[1]	1.9ab[2]	0.90a[2]	0.034a[2]
Soil washings	—	23.0b	2.4bc	0.58b	0.028a
Mycorrhizal inoculum	+	23.0b	2.7c	0.81ab	0.034a
Nonsterilized spoil material					
Control	—	15.5a	1.4a	1.14a	0.040a
Soil washings	—	24.8b	2.4bc	0.69b	0.023a
Mycorrhizal inoculum	+	26.3b	2.2bc	0.67b	0.048a

[1]*Means in the same column followed by the same letter do not differ significantly at 1% level.*
[2]*Means followed by the same letter do not differ significantly at 5% level.*

no P fertilizer and those receiving P fertilizer (table 3). Plants receiving P fertilizer had a greater dry weight than the control plants. Plants receiving the high fertilizer rate were approximately twice the weight of the control plants.

Corn plants grown in the spoil material with the low phosphorus rate were about 4 times taller and had 5 times greater dry weight than the control plants (table 3). Those plants receiving the high phosphorus rate were about 6 times taller and had 7 times greater dry weight than the control plants.

Discussion

Evidence presented in this paper further supports the theory of Aldon (1975), Daft and Nicolson (1974), and Daft et al. (1975) of the ecological importance of endomycorrhizal associations to plants initially colonizing mine spoil wastes in the West. The mycorrhizal fungus, *G. fasciculatus,* was found here to significantly increase survival and growth of rabbitbrush in sterilized and nonsterilized spoil material characterized by a very low phosphorus content (0.52 ppm extractable P) but with a pH (6.7) and nitrogen content (320 ppm NO_3) adequate for normal plant growth. However, this mycorrhizal fungus did not stimulate the growth of corn and fourwing saltbush in the same spoil material.

The survival and the growth response of rabbitbrush to mycorrhizal infection was attributed to an increase in uptake of phosphorus. This claim is indirectly substantiated by the significant increase in growth of rabbitbrush, corn and fourwing saltbush when phosphorus fertilizer was added to the spoil material.

The failure of *G. fasciculatus* to enhance the growth of fourwing saltbush apparently resulted from the inability of the fungus to infect the roots

Figure 3.—Corn plants grown in mine spoil material showing effects of 1.0, 0.3, and 0 g/pot of a 0-46-0 phosphorus fertilizer.

in the spoil material. This appears to be a type of host-microorganism specificity reaction (Mosse 1975), since Aldon (1975) found that *G. mosseae* was able to infect and increase the survival and growth of fourwing saltbush on McKinley mine spoil banks.

Table 3.—Effect of three levels of phosphorus fertilizer (0-46-0) on height (*cm*) and dry weight (*mg*) of rabbitbrush, fourwing saltbush, and corn.

Fertilizer level (g/pot)	Rabbitbrush[1]		Fourwing saltbush[1]		Corn[2]	
	Height	Weight	Height	Weight	Height	Weight
0	2.3a[3]	8a	10.3a	225a	14.0a	1200a
0.3	28.0b	276b	12.5a	345b	52.5b	6200b
1.0	28.0b	319b	12.5a	487c	76.3c	8500c

[1]*Grown for 137 days.*
[2]*Grown for 110 days.*
[3]*Column means followed by the same letter do not differ significantly at the 1% level.*

Another type of mycorrhizal specificity, effectivity (Mosse 1975) was evident with corn. *G. fasciculatus* was able to infect corn roots as evidenced by hyphae, arbuscules and vesicles in the roots, but did not increase phosphorus uptake or growth. In this experiment, the mycorrhizal plants were taller and had a greater dry weight than the nonmycorrhizal plants. However, this response could not be attributed to a mycorrhizal association since nonmycorrhizal plants growing in spoil material receiving soil washing also exhibited the same growth response.

This study suggests that rabbitbrush should be mycorrhizal prior to field planting. It also indicates that more detailed work is needed on specificity in endomycorrhizae as it influences the establishment of plants on strip-mined wastes.

References

Aldon, E. F. 1975. Endomycorrhizae enhance survival and growth of fourwing saltbush on coal mine spoils. USDA For. Serv. Res. Note RM-294, 2 p.

Aldon, E. F. and H. W. Springfield. 1975. Problems and techniques in revegetating coal mine spoils in New Mexico, p. 122-132. *In* Practices and Problems of Land Reclamation in Western North America. M. K. Wali (ed.) The Univ. of North Dakota Press, Grand Forks.

Bevege, D. I. 1968. A rapid technique for clearing tannins and staining intact roots for detection of mycorrhizas caused by *Endogone* spp. and some records of infection by Australian plants. Trans. Brit. Mycol. Soc. 51:808-810.

Daft, M. J. and T. H. Nicolson. 1974. Arbuscular mycorrhizas in plants colonizing coal wastes in Scotland. New Phytol. 73:1129-1138.

Daft, M. J., E. Hacskaylo and T. H. Nicolson. 1975. Arbuscular mycorrhizas in plants colonizing coal spoils in Scotland and Pennsylvania, p. 561-580. *In* Endomycorrhizas. F. E. Sanders, Barbara Mosse and P. B. Tinker (ed.) Academic Press, London.

Gerdemann, J. W. and T. H. Nicolson. 1963. Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting. Trans. Brit. Mycol. Soc. 46:235-244.

Ma, T. S. and G. Zuazaga. 1942. Micro-Kjeldahl determination of nitrogen. A new indicator and an improved rapid method. Ind. Eng. Anal. Ed. 14:280-282.

Marx, D. H. 1975. Mycorrhizae and establishment of trees on strip-mined land. The Ohio J. of Sci. 75:288-297.

Mosse, Barbara. 1975. Specificity in VA mycorrhizas, p. 469-484. *In* Endomycorrhizas. F. E. Sanders, Barbara Mosse, and P. B. Tinker (ed.) Academic Press, London.

Murphy, J. and J. P. Riley. 1962. A modified solution method for the determination of phosphate in natural waters. Anal. Chim. Acta. 27:31-36.

Schramm, J. E. 1966. Plant colonization studies on black wastes from anthracite mining in Pennsylvania. Amer. Philoso. Soc. 56:1-194.

Throneberry, G. O. 1974. Phosphorus and zinc measurements in Kjeldahl digests. Anal. Biochem. 60:358-362.

U S D A FOREST SERVICE
RESEARCH NOTE RM-344

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Survival of Three Grass Species After Inundation[1]

Earl F. Aldon[2]

SEP 8 1977

Abstract

Three grass species characteristically found in Southwestern areas that are periodically flooded were studied to determine how long they could remain under water and still survive. Desert saltgrass, alkali sacaton, and western wheatgrass were either totally or partially submerged for periods of 0, 3, 6, 12, and 24 days. All three species studies can survive at least 24 days of complete or partial inundation.

Keywords: *Distichlis stricta, Sporobolus airoides, Agropyron smithii,* revegetation.

Land managers often overlook plant placement in relation to topography in revegetation efforts. Germination of seeded stands or survival of transplants indicates success of plantings. Plants in low places that are likely to be inundated on occasion are seldom missed if they don't survive. Yet these places can be revegetated also if tolerant plants are used. This Note discusses some plants that can be grown successfully in these places.

The three grass species studied here are characteristically found in Southwestern areas subject to periodic flooding. The question we addressed was how long could they remain under water and still survive. A previous study of fourwing saltbush (*Atriplex canescens*) indicated 4-week-old shrub transplants were subject to high mortality if planted in areas likely to be inundated longer than a 30 hr period[3].

[1]*The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.*

[2]*Principal Hydrologist, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[3]*Aldon, Earl F. 1970. Fourwing saltbush survival after inundation. USDA For. Serv. Res. Note RM-165, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

Methods

Three grass species were tested for 0, 3, 6, 12, and 24 days partially and totally under water. Three replications (one plant each) of desert saltgrass (*Distichlis stricta*), alkali sacaton (*Sporobolus airoides*), and western wheatgrass (*Agropyron smithii*) were placed in large metal containers and either totally submerged in tap water or the crowns, but not the leaves, were covered with water. Water levels were held constant during the study. Prior to the study the plants had been grown for 6 months in alluvial soil in individual pots.

After the period of inundation, the plants were removed from the water and maintained in the greenhouse for 30 days to determine mortality. Vigor was evaluated visually on a scale of 1 = poor to 4 = very good the day after the submergence period ended and again 1 month later.

Results

All plants survived all treatments (table 1) and began growing vigorously after their removal from the water. There was no vigor difference between plants partially submerged and those totally submerged, so these data were combined in the statistical analysis. Desert saltgrass showed a significant loss in vigor the longer it was submerged and a significant recovery when measured 30 days later. After removal from water, saltgrass began sending up new plants, presumably from rhizomes. Western wheatgrass showed similar losses in vigor with increased submergence but a less clearcut recovery when measured 30 days later. Alkali sacaton showed an apparent loss in vigor after 24 days submergence and improvement 30 days later, but these were nonsignificant.

In general, the longer plants were submerged, the poorer their vigor when measured immediately after removal. When measured again a month later, overall vigor ratings of submerged plants had improved.

All three of these floodplain species can survive at least 24 days of complete or partial inundation.

Table 1.—Average vigor[1] of three grass species 1 day and 30 days after various inundation treatments.

Inundation treatment (Days)	Alkali sacaton		Desert saltgrass		Western wheatgrass	
	1 day	30 days	1 day	30 days	1 day	30 days
None	2.83	2.50	1.83ab[2]	1.67	3.00a	3.00
3	2.67	2.17	2.00a	3.50	2.67ab	2.50
6	2.50	2.50	1.83ab	2.83	3.50a	2.50
12	2.33	2.50	1.50ab	2.50	2.25ab	3.00
24	1.50	2.33	1.00b	2.17	1.75b	2.50

[1]Vigor ratings: 1 = poor; 2 = fair; 3 = good; 4 = very good.
[2]Column means having no letters are not different. Column means with the same letters are not significantly different at the 5% level.

SURFACE ENVIRONMENT & MINING
SEAM
PROGRAM

79, RM-345

une 1977

USDA FOREST SERVICE
RESEARCH NOTE RM-345

ORI ST SERVICE
DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

SEP 8 1977

Western Wheatgrass Transplants Grow Well on Raw Mine Spoil[1]

Dwight R. Cable[2]

Western wheatgrass plants grown in a nursery and set out in unweathered coal mine spoil survived and grew equally well whether mulched or not. Survival and growth during the year following planting, a very dry year, indicate that western wheatgrass plug transplants are well adapted to growing on raw coal mine spoil, and suggest that such transplants would be appropriate on small problem areas where direct seeding would have little chance of success.

Keywords: Rehabilitation, coal mine spoils, planting methods, *Agropyron smithii.*

Nursery-grown transplants can improve the chances for successful grass establishment on harsh, semiarid sites. This study was undertaken to determine the relative effectiveness of three planting methods, with and without straw mulch, on survival and subsequent vigor of western wheatgrass transplants on raw coal mine spoil at the McKinley mine, 20 mi (32 km) northwest of Gallup, N. Mex.

The wheatgrass was planted on essentially level, newly graded, unweathered overburden resulting from 1972 mining. The site is at an elevation of 6,885 ft (2,100 m) in the pinyon-juniper-sagebrush vegetation type, where annual precipitation averages about 15 in (38 cm).

The surface 12 in (30 cm) of material had a clay texture, with pH 7.3, electrical conductivity 5.02 mmhos, and 3.74% organic matter (somewhat high due to coal particles).

Methods

The plants were grown at the Coeur d'Alene Nursery in styroblock containers[3], with bullet-

[1]*The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a USDA Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.*

[2]*Principal Range Scientist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3]*Sjoberg, N. E. 1974. The styroblock container system. p. 217-228,* In *North Am. Containerized For. Tree Seedling Symp. Proc. Great Plains Agric. Publ. 68.*

shaped cavities 1 in top diameter, 4.5 in deep, filled with a vermiculite-peat moss potting mixture. C-30 seed grown by the Los Lunas Plant Materials Center in New Mexico was used.

The plants were 6 weeks old when planted on September 17, 1975. The leaves were trimmed to 3 in (7.5 cm) at the time of planting. Three tools were used for making the holes in which the plugs were inserted:

1. Planting bar, a wedge-shaped tool, which made a hole 3 in (7.5 cm) wide, 6 in (15 cm) deep, and tapering from 1 in (2.5 cm) thick at the top to a sharp edge at the bottom.
2. Posthole digger, which produced a circular hole 4 in (10 cm) diameter and 6 in (15 cm) deep.
3. Round bar, of the approximate shape of the grass plugs, which made a hole 1.5 in (3.8 cm) in top diameter and 5 in (12.5 cm) deep, tapering to a point at the bottom.

The field design consisted of 22 replications of six plants planted in a row, 1 ft (30.5 cm) apart, two plants for each hole type, with straw mulch placed around one plant of each pair. A total of 132 plants were planted.

During the 5 weeks before planting, precipitation at the site totaled 3.50 in (8.9 cm). At the time of planting, soil moisture content in the top 6 in (15 cm) varied from 7.2% to 23.8% for the 22 replications, representing a range in tension from about 1 bar to over 15 bars. During the 5 weeks after planting, precipitation at the site totaled only 0.45 in (1.1 cm). Precipitation during the 13 months following planting, until the evaluation in October 1976, totaled 7.87 in (20.0 cm), about 50% below normal.

Results

On October 19, 1976, 90% of the plants were still alive. Differences in mortality due to method of planting or mulching were not significant.

Vigor of the live plants was judged on a 4-point scale: 1 = poor, 2 = fair, 3 = good, 4 = very good. Mean vigor for plants in the six treatment combinations varied between 3.36 and 3.74:

Planting Method	Mulch	No Mulch	Mean
Planting bar	3.36	3.47	3.42
Posthole digger	3.71	3.65	3.68
Round bar	3.74	3.45	3.59
Mean	3.60	3.53	

Most plants produced new shoots from rhizomes, even though the year was very dry. Differences in vigor due to planting method or to mulching were not significant. There also was no correlation between soil moisture at the time of planting and subsequent mortality or vigor.

Conclusions

Western wheatgrass plug transplants are well adapted to growing on raw coal mine spoil, are drouth resistant, and do not require mulching or a specific planting technique for successful establishment. These results suggest that western wheatgrass transplants would be useful in establishing this grass on small problem areas where direct seeding would have little chance of success.

3,79:RM-346

1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-346

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

UTAH STATE UNIVERSITY LIBRARY
SEP
SCHOOL

Desert Rodent Abundance in Southern Arizona in Relation to Rainfall

Frank J. Turkowski[1] and J. Robert Vahle[2]

Desert rodent populations in southern Arizona fluctuated in rodent numbers and rodent species composition over a 30-year period. Data indicate that the direction of these annual fluctuations can be predicted from the amount of rainfall received during the previous year.

Keywords: Rodents, rainfall, desert.

Though information is available on rodent population fluctuations in more moderate climates, little is known about such populations in deserts, especially for an extended period. These animals often are exposed to habitat conditions related to low precipitation. Knowledge of how desert rodent species react to environmental conditions will contribute to a better understanding of small mammal population fluctuations.

[1]*Wildlife Biologist, U.S. Fish and Wildlife Service, Texas A&M Agricultural Research and Extension Center, P.O. Drawer 1051, Uvalde, Tex. 78801.*

[2]*Wildlife Technician, Rocky Mountain Forest and Range Experiment Station, located at the Forest Sciences Laboratory, Tempe, in cooperation with Arizona State University. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

In this study, rodent population density variations in desert grassland vegetation of southern Arizona were determined by a trapping census conducted during a 30-year period. Rodent abundance data is related indirectly to habitat conditions that respond to annual precipitation. Data were obtained from continuation of a project initiated by Reynolds (1958) on *Dipodomys merriami*. We are grateful to the late Hudson G. Reynolds who initiated the study and supervised data collection.

The study was conducted in mesquite-grassland along the Santa Rita Mountains on the Santa Rita Experimental Range about 56 km southeast of Tucson, Pima County, Ariz. The Range extends from an elevation of 884 m at its northern boundary to 1,311 m along the foothills of the Santa Rita Mountains. Annual rainfall on

the study site at the lower elevation averages 25.4 cm. There has been controlled cattle grazing on the area since 1915. The topography is flat, and soil varies from fine to coarse sandy loam.

The southwestern desert grassland climate generally is characterized by high rainfall and temperatures in summer, low rainfall and intermediate temperatures during spring, and low temperatures and intermediate rainfull during winter (Table 1). Average monthly precipitation varies from a low of 0.5 cm in May to a high of 10.7 cm in August. Mean monthly temperatures reach a low of 8°C in January and rise to a high of about 29°C in July. If rainfall is favorable, temperatures permit growth of some plants during winter. Additional plant growth begins after favorable summer rains.

Table 1.—Mean rainfall values (cm) at the Santa Rita Experimental Range study site, Arizona, 1942-1972.

	Rainfall category		
Season	Lowest years	Medium years	Highest years
Spring Feb.-May	4.0	6.3	4.0
Summer June-Sept.	10.0	19.0	27.5
Winter Oct.-Jan.	4.8	7.6	10.4
Total	18.4	33.0	41.9

Four snap-trap lines were set in December for 22 years during the period from 1942 through 1972 at each of three sites about 1.6 km apart. A trap line consisted of 10 museum special traps spaced 14 m apart and set for three successive nights. Three rat traps added to each line indicated the presence of larger rodents. The bait was rolled barley. Data from snap-trap lines were expressed as numbers of animals per species captured during the total of 468 trap nights a year.

Results and Discussion

Ten rodent species were trapped on the study area: Merriam and bannertail kangaroo rats, (*Dipodomys merriami* and *D. spectabilis*); Bailey (*Perognathus baileyi*) and desert pocket mice (*P. penicillatus*); grasshopper mouse (*Onychomys leucogaster*); cactus mouse (*Peromyscus eremicus*) and deer mouse (*P. maniculatus*); white-throated wood rat (*Neotoma albigula*); and two ground squirrels—the round-tailed ground squirrel (*Spermophilus tereticaudus*) and Yuma antelope squirrel (*Ammospermophilus harrisi*).

A total of 2,201 animals from 10,296 trap nights were taken during 22 sample years. The total rodent catch varied from 176 in 1959 to a low of 9 (all *D. merriami*) taken in 1943. *D. merriami* made up 73% of the total number of rodents trapped during the entire study period. Other significantly abundant species were *O. leucogaster*, which contributed more than 10%, *P. baileyi* (6%) and *P. penicillatus* (5%). All other species combined accounted for 6% of the total catch.

In the following discussion, numbers of animals trapped in December are considered to be representative of annual species populations. The annual combined total of all species populations fluctuated during the 22 years of data collection. The populations of individual species also varied greatly during successive years. For example, only 12 *D. merriami* were taken in 1954, while 135 were caught the next year; *O. leucogaster* increased from 1 to 7 from 1953 to 1954, and *P. penicillatus* increased from 3 to 27 from 1950 to 1951. Those species with lower population levels such as *D. spectabilis, P. eremicus, N. albigula* and *A. harrisi,* seemed to be more stable from one year to the next. Each rodent species reached population peaks and lows in different years.

Annual changes in species composition and total rodent numbers are difficult to explain since deaths, emigrations, immigrations, food abundance, floods, and droughts influenced the populations (Reynolds 1958). In desert habitats, however, rainfall could be one of the most important factors directly or indirectly influencing desert rodents.

All tests comparing total rodents and individual species numbers with the total rainfall for the same year were insignificant. However, the correlation for total annual rodent numbers approached significance with the amount of rainfall the previous year ($r^2 = 0.59$ and $P = 0.05$). The total average rainfall of years that preceded the top five rodent production years was 10.2 cm greater than the rainfall mean of years preceding the lowest five years. A similar significant difference of 8.8 cm was recorded when rainfall associated with the 11 peak years of rodent production was compared with the 11 lowest years.

Grouping annual rainfall totals into three broad categories showed a significant relationship between rodent numbers and rainfall (Table 2). In this analysis, annual rainfall categories were: low, 17.8-27.9 cm (7 years); medium, 27.9-38.1 cm (10 years); high, greater than 38.1 cm (5 years). Annual total rodent population was greatest when the previous year's rainfall was in the highest category. The total rodent populations of the years following lowest rainfall was about half that following the high rainfall years.

Annual population peaks of the different species did not coincide, suggesting that each one

Table 2.—Individual species abundance means on the Santa Rita Experimental Range in relation to rainfall categories.

Species	Rainfall category		
	Lowest years	Medium years	Highest years
Merriam kangaroo rat	40.3[b]¹	84.4[a]	93.2[a]
Bannertail kangaroo rat	1.1	0.2	0.4
Bailey pocket mouse	4.6 ± 1.2	8.3 ± 1.6	4.4 ± 1.6
Desert pocket mouse	5.4 ± 2.5	5.0 ± 2.5	3.6 ± 1.0
Grasshopper mouse	4.7[b]	14.4[a]	10.4[a,b]
Deer mouse	0.0	1.0	3.6
Cactus mouse	0.6	2.0	1.8
White-throated woodrat	2.1	1.6	0.4
Harris antelope squirrel	0.9	0.7	0.4
Roundtail ground squirrel	0.1	0.0	0.0
Total rodent population	59.9[a,b]	117.6[a]	119.2[a]
Previous year's rainfall (cm)	17.8-27.9	27.9-38.1	38.1-50.8

¹*Values within a column with unlike superscript letters are statistically different ($P < .05$).*

reacted differently to environmental factors. Total *D. merriami* numbers increased from an average population size of 40.3 during years in the low rainfall category to 84.4 during average years, and 93.2 in years following heavy rainfall. However, *D. spectabilis* and *N. albigula* were at their highest densities when preceding years' rainfall was least. Species that were most abundant when associated rainfall was greatest were *D. merriami, P. manicultatus* and *A. harrisi.*

P. maniculatus usually had low populations during years when other rodents were at population peaks. For example, the three greatest years for the total of the other rodents were 1945, 1955, and 1959. During these years, only one *P. maniculatus* was taken. Although populations of this species were enhanced during the years with the greatest amounts of rainfall, they did not reach levels near one per trap night as reported by Hoffman (1955) in Mono County, Calif.

There seemed to be reverse trends in populations numbers between *D. spectablis* and *N. albigula. D. spectabilis* was represented during only 4 of the 12 years that *N. albigula* was taken.

Reynolds (1958) reported little competition between rodents on the Santa Rita because of feeding behavior and preferences. Comparisons of population levels of the seed-eating rodents (*Dipodomys* spp. and *Perognathus* spp.) indicated that, in 1955, when *D. merriami* was at its greatest density, other seed-consuming species such as *D. spectabilis* and *P. baileyi* were not taken, and *P. penicillatus* was at a low level. Likewise, the greatest populations of these latter three species were attained during years when *D. merriami* was at low densities. The low population years of the three rodents might be due to reasons other than food competition with *D. merriami,* since the four species differ in feeding behavior and preferences (Vorhies and Taylor 1922, and Reynolds 1958).

Precise seasonal habitat information was not obtained throughout the 30-year study period. However, Reynolds (1958) reported on seasonal environmental influences on the Santa Rita rodents during the period from 1943-1952. He found that kangaroo rat numbers were greatest in July when immature animals were most abundant. Examination of the December trapping survey data revealed no correlations between percentages of immature individuals in the annual rodent population and rainfall of the same year or previous years. There were also no significant differences when percentages of immature individuals in the entire rodent population during years with less than 5.0 cm of October through January rainfall were compared with years in which rainfall was greater than 5.0 cm.

Because most of the rodents on the study area had the potential to produce several litters annually, it appears that their populations should increase during a year of heavy precipitation, especially if the rainfall precedes the summer breeding season. However, heavy downpours seem to depress populations due to flooding of the rodent burrows (Fitch 1948, Grinnel 1939, Reynolds 1958).

The amount of rainfall during the previous year seemed to influence the population numbers of most of the rodent species. Smith et al. (1974) also considered the previous years' rainfall as the most important weather variable in a small mammal population in a hardwood forest in South Carolina. Seed-eaters and species more indirectly associated with grasses or forbs such as *O. leucogaster* and *Peromyscus* spp. increase when rainfall enhances plant growth. When these species are at low population levels, competitors or marginal species apparently are favored. *D. spectabilis* and *N. albigula* populations appear to be more independent of rainfall.

Relating rainfall classes to species population levels indicates that most of the other desert rodents benefit when rainfall during the previous year is 27.9 cm or more. However, precipitation above 38.1 cm does not increase proportionately the total annual production of rodents. Perhaps intrinsic factors such as territorial competition are more important at high population densities, or environmental factors, such as increased cover for predators, tend to suppress the high populations. Though there are a wide variety of factors influencing desert rodent numbers, it appears that the direction of annual population fluctuations can be predicted from the amount of rainfall during the previous year.

Literature Cited

Fitch, H. 1948. Habits and economic relationships of the Tulare kangaroo rat. J. Mammal. 29:5-35.

Grinnel, J. 1939. Effects of a wet year on mammalian populations. J. Mammal. 20:62-64.

Hoffman, R. S. 1955. A population-high for *Peromyscus maniculatus.* J. Mammal. 36:571-572.

Reynolds, H. G. 1958. The ecology of the Merriam kangaroo rat (*Dipodomys merriami* Mearns) on the grazing lands of southern Arizona. Ecol. Monog. 28:111-127.

Smith, M. H., J. B. Gentry, and John Pinder. 1974. Annual fluctuations in small mammal populations in an eastern hardwood forest. J. Mammal. 55:231-234.

Vorhies, C. T. and W. P. Taylor. 1922. Life history of the kangaroo rat, *Dipodomys spectabilis spectabilis* Merriam. U.S. Dep. Agric. Bull. 1091. 39 p.

tember 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-347

OREST SERVICE
I.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of Watering, Shading, and Size of Stock on Survival of Planted Lodgepole Pine

Norman Baer, Frank Ronco, and Charles W. Barney[1]

During a summer with above-normal precipitation, watering, shading and size of stock had no significant effect on survival of planted lodgepole pine. During a summer with below-normal precipitation, however, shading increased survival significantly, and larger stock survived better than smaller stock.

Keywords: *Pinus contorta*, survival, forest regeneration (artificial), shading, water stress.

Adequate survival has been difficult to obtain with planted lodgepole pine (*Pinus contorta* Dougl.) on large clearcut areas on the Bighorn National Forest in north-central Wyoming. Observations in these plantations led to the presumption that high moisture stress resulting from drought was a major factor contributing to mortality.

Severe moisture stress in planted seedlings can be directly controlled by irrigating, but such practice is generally considered impractical in Rocky Mountain forests. Indirect methods of controlling water stress, in contrast, may be applicable under field conditions. One approach to controlling water stress has been shading (Otter 1964, Adams et al. 1966, 1967, Gordon 1970, Ronco 1970). Shading not only reduces water loss from the soil surface, but also decreases seedling transpiration (Stoeckeler 1970). Another method might be to control seedling size, since extensive root systems of large seedlings absorb soil moisture more effectively than underdeveloped roots (Wahlenberg 1928, Kramer and Koslowski 1960).

The objectives of this study were to test the effects of treatments aimed at alleviating severe moisture stress, and to determine the reasons for plantation failure, with emphasis on evaluating the effectiveness of shading in reducing seedling mortality.

Methods and Materials

The study was designed as a 2^3 factorial to test the effects of two levels of water, shade, and seedling size on survival. Seedlings were either irrigated at regular intervals during the first growing season to maintain a high level of soil moisture in the root zone, or they received no water other than natural precipitation. In the shade treatment, seedlings either were shaded by an 8-in wide cedar shingle inserted into the ground on the south side of the seedling at an angle such that the top of the shingle was directly over the tip of the seedling, or they received full sunlight. The two seedling sizes (above-average and below-average) were determined by estimating stem caliper and volume of roots and shoots.

Seedlings were 2+0 stock grown in the Mt. Sopris Nursery, Basalt, Colo., from seed collected on the Bighorn National Forest.

[1]*Research Associate, Horticulture and Forestry Department, South Dakota State University, Brookings; Principal Silviculturist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.; Professor, Department of Forest and Wood Sciences, Colorado State University, Fort Collins, Colo.*

Study areas were on two sites on the Bighorn National Forest, one near Webb Creek in the southern part of the Forest and the other near the East Fork of the Tongue River in the north. In the spring of 1973, 10 blocks were planted in each experimental area — Webb Creek was planted on June 6 and East Fork on June 12. Each block contained 80 seedlings arranged in 8 rows of 10 seedlings each. Spacing within and between rows was 4 ft. Treatments were then randomly assigned to rows within a block. Seedlings were watered at 2-week intervals during the summer of 1973 to maintain adequate soil moisture, but watering was discontinued during the summer of 1974. Thus, the effect of supplemental watering could be tested for only the first growing season and for any subsequent residual effect. Shading was discontinued after the 1974 growing season.

The experiment was replicated in 1974 on an identical set of blocks adjacent to those established in 1973; planting dates were June 20 and June 25, respectively, on the Webb Creek and East Fork areas. Seedlings in this planting were shaded during the summer of 1974. The proposed watering schedule could not be maintained, however, so analyses of the 1974 plantings were limited to comparisons of the effects of shade and size of stock.

Survival counts were made biweekly throughout the 1973 and 1974 growing seasons. In addition, a final observation was made in the fall of 1975 to determine any residual effect of shading and watering. The cause of mortality was recorded for individual seedlings whenever possible.

A hygrothermograph and a trough rain gage were installed on both experimental areas. Survival data were tested by analysis of variance using an arcsin transformation.

Results

1973 Plantings

Survival after two growing seasons on the Webb Creek plots averaged 94% over all treatments (table 1). None of the treatments had any significant effect on survival after two growing seasons, so data were combined for seedlings at above-average and below-average size. Similarly, none of the treatments significantly affected survival on the East Fork plots. Even at the end of the third growing season — during which seedlings were neither watered nor shaded — no significant differences in survival had developed among treatments on either the Webb Creek or East Fork plots, indicating an absence of any residual effects. Total survival after three growing seasons was 89% on Webb Creek and 87% on East Fork. There was no interaction between shade and water treatments.

Table 1.—Percent survival of lodgepole pine seedlings on Webb Creek and East Fork during three growing seasons following spring planting in 1973 (n = 100)

	Treatments				
Year	Watered	Shaded	Watered and shaded	Control	Mean[1]
			Webb Creek		
1973	98	98	100	98	98
1974	91	95	96	94	94
1975	84	90	91	88	89
			East Fork		
1973	96	98	98	96	97
1974	94	94	96	90	93
1975	87	87	90	83	87

[1]*No significant differences (P = .05) between mean values.*

1974 Plantings

At the end of the first growing season on the Webb Creek plots, shading had significantly increased survival: 96% compared with 86% for unshaded seedlings (table 2). Similarly, survival of shaded seedlings was 95% versus 81% for unshaded seedlings on the East Fork plots. Survival for all treatments was 91% on Webb Creek and 88% on East Fork.

Although shading was discontinued after the first summer, its residual effect was still significant on both study areas at the end of the second growing season. Furthermore, size of stock — which apparently had no effect on survival on the Webb Creek plots during the first summer — significantly affected survival after two growing seasons. Survival of above-average-size stock was 82%, while below-average-size stock averaged only 74%. Average survival after two summers was 78% on Webb Creek and 67% on East Fork. There was no interaction between size and shade treatments.

Causes of Mortality

Mortality due to browsing by big game animals and gophers was minimal during these experiments. The most extensive damage, in the 1973

Table 2.—Percent survival of lodgepole pine seedlings on Webb Creek and East Fork during two growing seasons following spring planting in 1974 (n = 100)

Year and size of stock	Treatments		
	Shaded[1]	Control	Mean[2]
	..... Webb Creek		
1974			
Above-Average	96	88	92_a
Below-Average	95	84	91_a
Mean[2]	96_a	86_b	91
1975			
Above-Average	86	79	82_a
Below-Average	80	69	74_b
Mean[2]	83_a	74_b	78
	..... East Fork		
1974			
Above-Average	94	80	87_a
Below-Average	96	82	89_a
Mean[2]	95_a	81_b	88
1975			
Above-Average	72	65	68_a
Below-Average	75	58	66_a
Mean[2]	74_a	62_b	67

[1]*Shaded only during 1974 growing season.*
[2]*Unlike subscripts denote a significant difference (P = .05) between mean values.*

Webb Creek planting, amounted to only 15 seedlings, or approximately 2% of the 800 seedlings planted (table 3). Of the identifiable causes of mortality, drought or water stress accounted for most of the losses on both study areas in all years.

Discussion and Conclusions

Neither the direct effects of watering on seedling survival, nor its applicability towards identifying water stress as a potential cause of mortality was determined in this study. Nevertheless, some conclusions can still be drawn regarding the basic hypothesis that drought is a critical factor in lodgepole pine plantations on the Bighorn National Forest. It is obvious that, during years such as 1973 when rainfall is abundant and well distributed throughout the growing season, water stress is not likely to be a major cause of mortality. In fact, in these experiments, survival was still high after 3 years, even though one of them was dry. Conversely, plantations established in a dry year, such as 1974, can be expected to suffer greater losses from water stress. Furthermore, increasing mortality can be expected in subsequent years, apparently due to the residual effect of water stresses developed in seedlings during the first year after planting.

It appears that losses due to severe moisture stress can be significantly reduced simply by shading. During dry periods, shade most likely creates a more favorable internal water balance by decreasing evapotranspiration (Kramer 1969, Stoeckeler 1970). During wet years however, shade does not increase survival, presumably because adequate soil moisture prevents high moisture stress. During dry years, shade appears to be nearly as effective as maintaining adequate soil moisture in reducing losses from drought. Survival of shaded seedlings in the 1974 planting was 95% and 96% on the Webb Creek and East Fork plots, respectively. Thus, the maximum increase in survival obtainable in this year by watering shaded seedlings would apparently have been 4% to 5%.

The relationship between seedling size and survival was similar to that produced by shade, in that this treatment influenced survival only during dry years. Seedling size increased survival only for the 1974 planting when low precipitation of 0.2 and 0.9 in was recorded on Webb Creek and East Fork, respectively, during the 2- to 3-week period after planting. Contrary to normal expectations, however, no differences in survival due to seedling size were apparent the first year. Not until the second growing season, and then only on the Webb Creek plots which received the least precipitation, were any significant differences in survival observed. It appears, therefore,

Table 3.—Percent mortality in each experimental planting at the end of the 1975 growing season

Location and year planted	Cause of Mortality				
	Pocket gopher	Big game browsing	Drought	Unknown	Total
Webb Creek					
1973	1	1	3	6	11
1974	0	1	17	4	22
East Fork					
1973	1	1	5	6	13
1974	0	0	24	10	34

that larger stock survives better than smaller stock only under drought conditions on drier sites. Apparently, root systems of small seedlings absorb adequate moisture during wet years, but under drought conditions, water uptake is sufficient only in large seedlings with well-developed root systems.

The data also indicate that lodgepole pine can be successfully regenerated without special treatment when precipitation is plentiful during the subsequent growing season. During a dry year, however, survival of planted seedlings may be too low to insure satisfactory stocking unless the planting rate is increased or seedlings are irrigated or protected by shading.

Literature Cited

Adams, Ronald S., John R. Ritchey, and W. Gary Todd. 1966. Artificial shade improves survival of planted Douglas-fir and white fir seedlings. Resour. Agency, Dep. Conserv., Div. For., State For. Note-28, 11 p. Sacramento, Calif.

Adams, Ronald S., Samuel J. Gossard, and John R. Ritchey. 1967. Shade but not top pruning improves survival of Monterey pine. Resour. Agency, Dep. Conserv., Div. For., State For. Note-34, 9 p. Sacramento, Calif.

Gordon, Donald T. 1970. Shade improves survival rate of out planted 2-0 red fir seedlings. USDA For. Serv. Res. Note PSW-210, 4 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Kramer, P. J. 1969. Plant and soil water relationship: A modern synthesis. 482 p. McGraw-Hill Book Co., N.Y.

Kramer, P. J., and T. T. Koslowski. 1960. Physiology of trees. 542 p. McGraw-Hill Book Co., N.Y.

Otter, Floyd L. 1964. Artificial protection of first year natural seedlings on the Mountain Home State Forest in 1963. Resour. Agency, Dep. Conserv., Div. For., State For. Note-22, 5 p. Sacramento, Calif.

Ronco, Frank. 1970. Shade and other factors affect survival of planted Engelmann spruce seedlings in Central Rocky Mountains. USDA For. Serv. Res. Note RM-163, 7 p. Rocky Mt. For. and Range Exp. Stn. Fort Collins, Colo.

Stoeckeler, J. H. 1970. The United States of America. p. 268-346. *In* Afforestation in arid zones. R. N. Kaul (ed.) Monogr. Biol. 20. Junk Publ., The Hague. 435 p.

Wahlenberg, W. G. 1928. Experiments with age classes of stock suitable for forest planting the Northern Rocky Mountains. J. Agric. Res. 36:977-1000.

tember 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-348

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STAT ON

Snow Accumulation and Melt in Sprayed and Undisturbed Big Sagebrush Vegetation

David L. Sturges[1]

The influence of big sagebrush control on snow accumulation and melt was studied in a location where wind is an important snow relocation agent. A small (≤5 cm) but significant reduction in snow accumulation was detected before vegetation was covered by snow on plots sprayed with 2,4-D compared to plots with untreated vegetation.

Sagebrush control had no effect upon maximum depth of snow accumulation or snowmelt rates. Snow deposition at the experimental site was controlled by topographic factors once snow depth exceeded vegetation height.

Keywords: *Artemisia tridentata*, snow accumulation, snowmelt.

DEC 7 19

Snow accumulation and melt characteristics on sagebrush lands have not received the attention given to forested lands. An early study by Connaughton (1935) in Idaho showed that snow accumulation characteristics on a plot denuded of vegetation was similar to a plot with big sagebrush (*Artemisia tridentata*) vegetation. A stand of mature timber accumulated only about 75% as much snow as bare or sagebrush plots because of interception losses. Melt rates on bare and sagebrush plots were almost identical, but plots with a forest cover retained snow 4 to 8 days longer depending on canopy density.

[1]*The author is Research Forester, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, with central headquarters maintained at Fort Collins in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Laramie, Wyo., and was supported in part by the Bureau of Land Management, U.S. Department of the Interior.*

Sonder and Alley (1961) were the first to describe the effects of big sagebrush control on snow accumulation. They reported no difference in accumulation for sprayed and unsprayed vegetation in the Red Desert of Wyoming where drifting is common. At another study location in the Bighorn Mountains of Wyoming, sprayed vegetation retained snow longer in the spring than unsprayed vegetation. Snow measurements were taken once in the spring, 6 and 7 years after control. Snow depth was 60 centimeters in the sprayed sagebrush stand and 20 centimeters in the unsprayed sagebrush stand in the sixth year after spraying. The following year, snow was 25 and 21 centimeters deep on the sprayed and unsprayed areas, respectively.

Intensive snow depth and density measurements were taken by Hutchison (1965) on adjacent plots dominated by mountain big sagebrush (*A. t.* sub. *vaseyana*) and grasses at a site 2,900 meters in elevation in northwest Wyoming. The

plots were on level ground to minimize snow trapping due to topography. Even though drifting was minimal, sagebrush plots accumulated significantly more snow early in the winter because sagebrush crowns caused greater snow deposition. Accumulation rates were similar for both types of vegetation once sagebrush crowns were covered, but the initial difference in depth persisted through the winter. Average melt rates determined over an 8-day period were also similar, 0.97 and 1.14 centimeters per day for grass and sagebrush vegetation, respectively.

Methods

This report describes a plot study that was conducted to learn if spraying big sagebrush affects snow accumulation, maximum snow depth, or the snowmelt rate. A continuous record of snowmelt was also obtained during two springs from a snowmelt lysimeter located in undisturbed big sagebrush vegetation.

Work was performed at the Stratton Sagebrush Hydrology Study Area located in southcentral Wyoming, 29 kilometers west of Saratoga. The Stratton area is 2,225 meters in elevation and receives about 500 millimeters of precipitation annually. About two-thirds of total precipitation falls as snow; accumulation begins in November, and melt begins in April or May. The average monthly windspeed increases from about 22 kilometers per hour in November to 32 kilometers per hour in January, and then progressively decreases to 19 kilometers per hour in April. Because of strong winds, much of the snow that falls is quickly relocated from windward slopes and ridges into natural accumulation zones. The location of accumulation zones is controlled by the topography in combination with prevailing wind direction.

The experimental site was in a moderate snow accumulation zone on the lower portion of a north-facing hillside. A dense stand (47,100 plants per hectare) of mountain big sagebrush was present at the study site before treatment. About two-thirds of the sagebrush plants were between 30 and 50 years old. Individual plants averaged 34 centimeters tall, and the stand had a live, leafy crown intercept of 28%. Total herbaceous production was 1,423 kilograms per hectare the year before spraying. Sagebrush contributed 73% of total production; 23% was contributed by grasses, and the remaining 4% was contributed by forbs. Idaho fescue (*Festuca idahoensis*) and various bluegrasses (*Poa* spp.) were the dominant grass species.

Fourteen 0.4-hectare plots were established on the hillside in 1968. The plots were located in two strips that were 8 and 6 plots long, arranged in a randomized block design. Each block consisted of two plots that were randomly assigned to either the spray or nonspray treatment. Plots also were utilized to study the effects of sagebrush control on the soil moisture regime (Sturges 1977).

Snow accumulation decreased up the hillside because of an interaction between site location and prevailing wind direction. Consequently, average plot snow depth was determined from measurements made along one transect that was perpendicular to the slope and another that was parallel to the slope. Seven snow depth measurements, spaced at 9-meter intervals, were taken on each transect. Measurements were made about once a month through the accumulation period and more frequently during the melt period. A variance analysis, based on average plot snow depth, was performed for each measurement date. Treatment differences were accepted as statistically significant at the 0.05 probability level. Snow density was determined only at a single point near the center of each plot on each measurement date to indicate average density across the experimental site.

Snow accumulation was measured during the winter of 1969-70 to identify variability in snow deposition at the site before sagebrush control. Posttreatment snow measurements were made during the snow accumulation phases of the winters of 1970-71, 71-72, and 72-73, the first through third winters after sagebrush control. Intensive snow depth measurements were made during the 1971, 1973, and 1974 snowmelt seasons.

Treatment plots were sprayed with 2,4-D in June 1970, killing more than 95% of the plants. Remaining live plants were hand sprayed the following spring to achieve as complete a control as possible. Sagebrush skeletons were left intact, and, except for small branchlets, little breakdown of skeletal material had occurred by the fourth posttreatment winter.

Daily Snowmelt

A continuous record of snowmelt was obtained during the 1973 and 1974 melt periods using a snowmelt lysimeter patterned after the instrument designed by Haupt (1969). The meter was located on an unsprayed plot where snow accumulation was similar to average accumulation on all untreated plots. The meter was 61 centimeters square, but was modified from Haupt's design by enclosing a sagebrush plant within the meter and by using butyl rubber to form the bottom of the lysimeter. The sagebrush plant was about 40 centimeters tall, and its canopy covered approximately two-thirds of the meter area. Plastic sheeting was attached to the metal plot boundary and formed the lysimeter walls; the sheeting was pulled up periodically during the winter to isolate the snow column over the meter. Plastic that extended above the snow surface was cut away frequently during the melt season to minimize the lysimeter's effect on microclimatic conditions. Melt water drained from the meter to a storage reservoir. A FW-1 water level recorder was placed on the reservoir to provide a continuous record of inflow.

Results

Snow Accumulation Characteristics

Pretreatment.—Snow accumulation characteristics reflected topographic location of the experimental site in relation to wind speed and direction, vegetation height, and precipitation. Snow accumulation began in early November, and maximum depth was measured April 18 (table 1). Winter precipitation was the lowest recorded during any year of study.

Pretreatment measurements indicated that snow depth was slightly greater on plots that were to receive the spray treatment than on plots that were to remain in an undisturbed state (table 1). However, differences were not statistically significant. Treatment differences ranged from 1 centimeter, on the first measurement date when snow was about 30 centimeters deep, to 3 centimeters, when snow depth exceeded 60 centimeters. Any differences evident after spraying are attributable to sagebrush control.

The relative influence of vegetation and topography on snow accumulation changed as the winter advanced. Plot snow depths were relatively uniform early in the winter while sagebrush extended above the snow surface and little snow was transported onto the experimental site. Large differences developed, however, after sagebrush was covered by snow and accumulation became largely a function of location on the hillside. By March, snow was about 45 centimeters deep on the set of plots that straddled a slight ridge, and about 80 centimeters deep where deposition was most pronounced (table 1).

Table 1.—The range and average snow depth (cm) for plots assigned to spray and nonspray treatments, and average snow density, the winter before spraying.

Date	Range		Average		Snow density
	Nonspray	Spray	Nonspray	Spray	
11/09	23-36	24-42	30	31	0.25
02/05	48-67	41-81	57	58	.34
03/05	41-76	46-85	60	63	.33
03/16	42-78	48-86	61	64	—
04/18	65-100	70-109	86	89	.34
05/08	7-54	19-70	41	45	.40

Posttreatment.—Snow depth on untreated plots the first measurement date after spraying was nearly the same as on the first measurement date the winter before treatment. However, sprayed plots had 2.5 centimeters less snow than untreated plots, the reverse of accumulation characteristics before spraying (fig. 1). When snow was next measured on January 13, sprayed plots had 76 centimeters of snow, 3 centimeters more snow than on unsprayed plots. Once sagebrush was covered by snow, the accumulation pattern reverted to that evident before spraying.

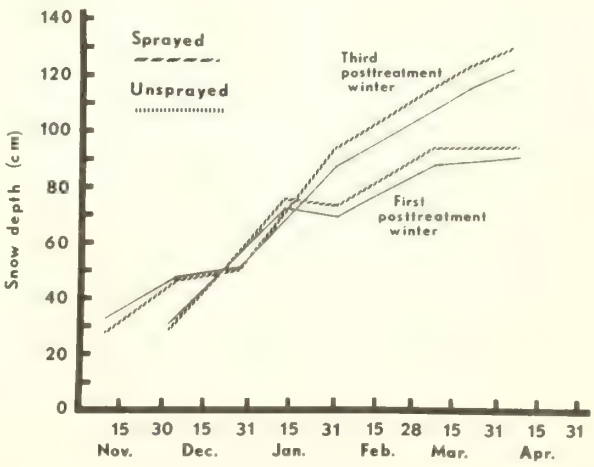


Figure 1.—Snow accumulation for sprayed and unsprayed sagebrush treatments the first and third posttreatment winters.

The first measurement taken the second winter after treatment, on November 5, 1972, indicated that snow was significantly deeper on unsprayed plots (20 centimeters) than on sprayed plots (17 centimeters). The treatment difference decreased to 1 centimeter December 10, when snow was about 45 centimeters deep. At that time, topography had begun to strongly influence deposition of wind-blown snow because vegetation was nearly submerged in the snowpack. Snow was about 70 centimeters deep on January 7, and the accumulation pattern on individual plots had reverted to that evident before spraying.

Data collected the third posttreatment winter verified that accumulation of snow on sprayed plots early in the winter was significantly less than on unsprayed plots (fig. 1). Unsprayed plots had 5 centimeters more snow than sprayed plots November 9, 1973. Thereafter, the rate of snow deposition was greater on sprayed plots as vegetation exerted less and less influence on accumulation. By December 28, the snow surface was at the top of sagebrush crowns, and unsprayed plots had only 1 centimeter more snow than sprayed plots. Snow depth increased more than 35 centimeters in the next month, and accumulation patterns reverted to those evident before spraying when topography was the primary factor controlling deposition once vegetation was covered.

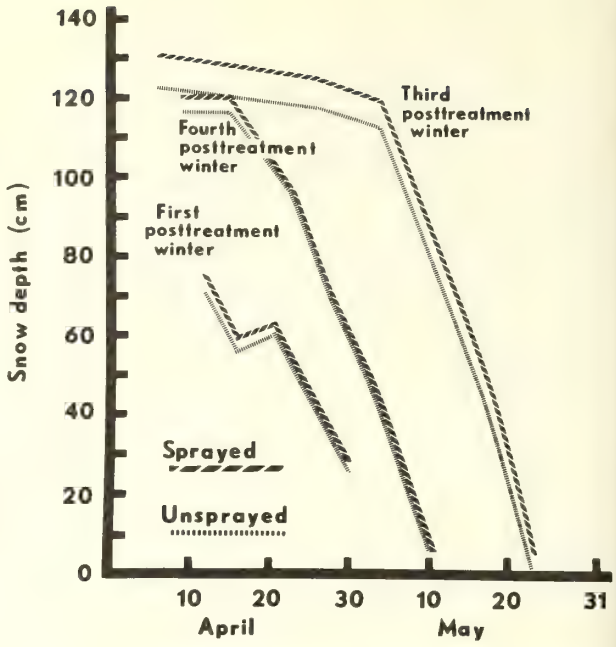


Figure 2.—Snow depths for sprayed and unsprayed sagebrush treatments during the melt period.

Snowmelt Characteristics

Pretreatment.—The difference in average snow depth at the time of maximum accumulation on plots assigned to spray and nonspray treatments persisted through snowmelt. Snowmelt was similar on all plots between April 18 and May 8 (table 1). Measurements indicated that snowmelt characteristics, as well as accumulation characteristics, were similar for treatments before sagebrush control.

Posttreatment.—Sprayed plots always had slightly more snow at the time of maximum accumulation than unsprayed plots, but a similar difference also was evident the winter before spraying. The small, but nonsignificant difference, persisted through the melt period. Snowmelt began between early April and early May in the three springs that intensive measurements were taken (fig. 2). Snow disappeared rapidly every year, regardless of the time that melt began.

The similarity in snow depth through the melt period each spring on sprayed and unsprayed plots suggests that treated and untreated plots had similar melt rates. There were two intervals (10 and 4 days long) in the 1971 melt season and two intervals (6 and 7 days long) in the 1973 melt season when it was possible to directly compare the change in snow depth. Treatment differences were not significant for any period. In 1971 there was a 1 centimeter difference between treatments in both measurement intervals, and treatments lost identical amounts of snow in the two intervals during 1973.

Snow still covered the vegetation during the 1971 and 1973 analysis periods. Therefore, these analyses did not provide a definitive test of whether or not the rate of snowmelt was affected by sagebrush control when the snow surface was within the vegetation canopy. To insure that snowmelt was being influenced by plot vegetation, data were segregated into intervals when (a) plot snow depth was no deeper than 70 centimeters at the beginning of the interval and (b) at least half the measurement points on a plot were snow covered at the end of the interval. Data meeting these prerequisites were available just for the 1971 melt season and then only for five of the seven blocks (table 2). The variance analysis

removed climatic factors as a source of variation before testing for a treatment difference. Unsprayed plots lost an average of 32 centimeters of snow while sprayed plots lost 31 centimeters of snow, a nonsignificant difference. There is no evidence from this study to indicate that spraying had an appreciable effect on snowmelt at any time during the melt interval.

Table 2.—The influence of sprayed and unsprayed vegetation on snowmelt in 1971 when snow was located within the vegetation canopy.

Interval		Change in depth (*cm*)	
From	To	Unsprayed	Sprayed
4/30	5/05	29	26
4/21	4/30	35	37
4/21	4/30	36	36
4/02	4/12	21	22
4/21	4/30	37	34
Aver.		32	31

Daily Snowmelt

The snowmelt lysimeter was in operation during the 1973 and 1974 melt seasons (fig. 3). Snowmelt started April 25, 1973, 27 days later than in 1974, which is typical of year to year climatic variations in the mountain big sagebrush type. The delayed start of snowmelt in 1973 was combined with extremely high melt rates and triggered flow over the snow surface, an unusual hydrologic phenomenon first described on the Stratton Study Area (Sturges 1975).

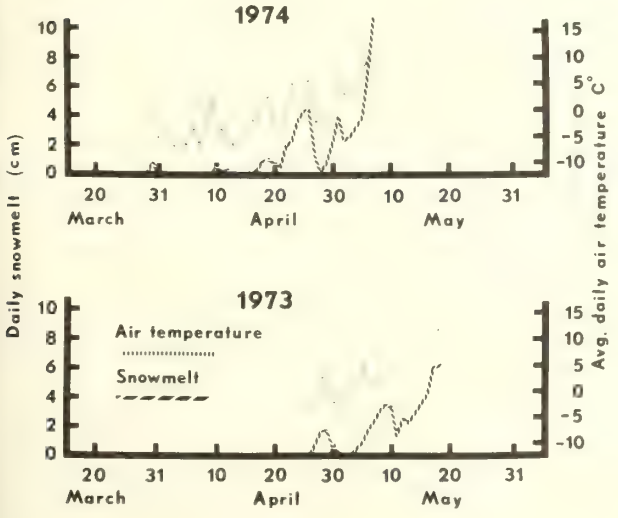


Figure 3.—Daily snowmelt at the snowmelt lysimeter in 1973 and 1974.

Melt commonly released 2 centimeters of water a day while snow covered the sagebrush plant. The rate of melt accelerated sharply when the snow surface reached the sagebrush crown; about 6 centimeters of water a day were released on the last two full days of melt in 1973. The acceleration in melt was caused by a change in energy relations once vegetation protruded through the snow. A continuous snow surface reflects much of the incoming solar radiation, but vegetation efficiently absorbs short-wave radiation. Vegetation then conducts heat directly to the snow. More important, short-wave energy absorbed by vegetation is reradiated as long-wave radiation, which is readily absorbed by snow. As a result, much more of incoming solar energy is used to melt snow when vegetation extends above the snow surface than when the snow cover is continuous. About 15 centimeters of snow depth-loss was required to release 6 centimeters of water in this study and snow disappeared rapidly once the surface was within the sagebrush canopy.

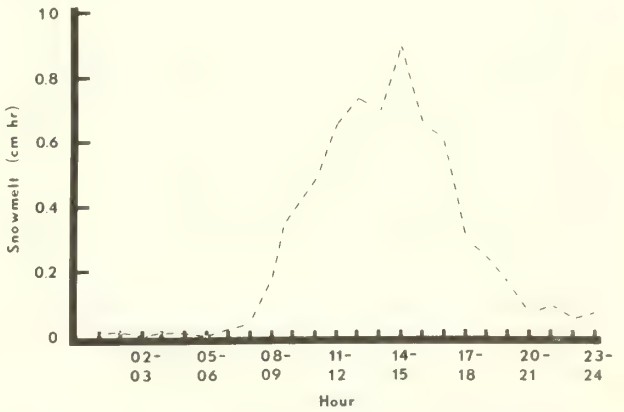


Figure 4.—Average hourly snowmelt rate on three dates when total melt ranged from 6 to 7 centimeters of water per day.

Average hourly snowmelt rates were calculated from data collected on the three days when melt released between 6 and 7 centimeters of water (fig. 4). Though the maximum melt rate was much lower than rainfall intensity during summer convectional storms, it still was substantial. Maximum melt occurred between 2 and 3 p.m. when 0.9 centimeter of water was released. The rate of snowmelt exceeded 0.2 centimeter of water per hour between 9 a.m. and 7 p.m. and exceeded 0.6 centimeter per hour for 6 hours during the day. Thus, the acceleration in melt rate which occurred when the snow surface was within the vegetation canopy was an important but short-lived hydrologic process.

Summary and Conclusions

Snow accumulation was uniform across the experimental site early in the winter when the snow level was below the top of sagebrush plants and snow transport by wind was minimal. Once vegetation was covered by snow, topography and precipitation largely determined additional snow accumulation. Consequently, snow depth on individual plots at the time of maximum accumulation differed substantially even though the study site appeared to have uniform characteristics in a snow-free condition.

Before snow covered the vegetation, snow accumulation was reduced significantly on sprayed plots compared to unsprayed plots. Absolute differences were small, however, and never exceeded 5 centimeters. Accumulation was not affected by sagebrush control once snow covered the vegetation.

The rate of snowmelt was not affected by sagebrush control during the time vegetation was submerged within the snowpack or during the time the snow surface was within the vegetation layer.

A continuous record of snowmelt was obtained from a single lysimeter during 1973 and 1974. Melt rates of 2 to 4 centimeters of water a day were common when snow covered the sagebrush plant, but accelerated to 6 centimeters or more when snow was within the sagebrush canopy. The maximum average hourly snowmelt rate was 0.9 centimeter of water on days when melt released 6 to 7 centimeters of water. Snowmelt exceeded 0.6 centimeter of water per hour for 6 consecutive hours during the day.

Literature Cited

Connaughton, Charles A. 1935. The accumulation and rate of melting of snow as influenced by vegetation. J. For. 33:564-569.

Haupt, Harold F. 1969. A simple snowmelt lysimeter. Water Resour. Res. 5:714-718.

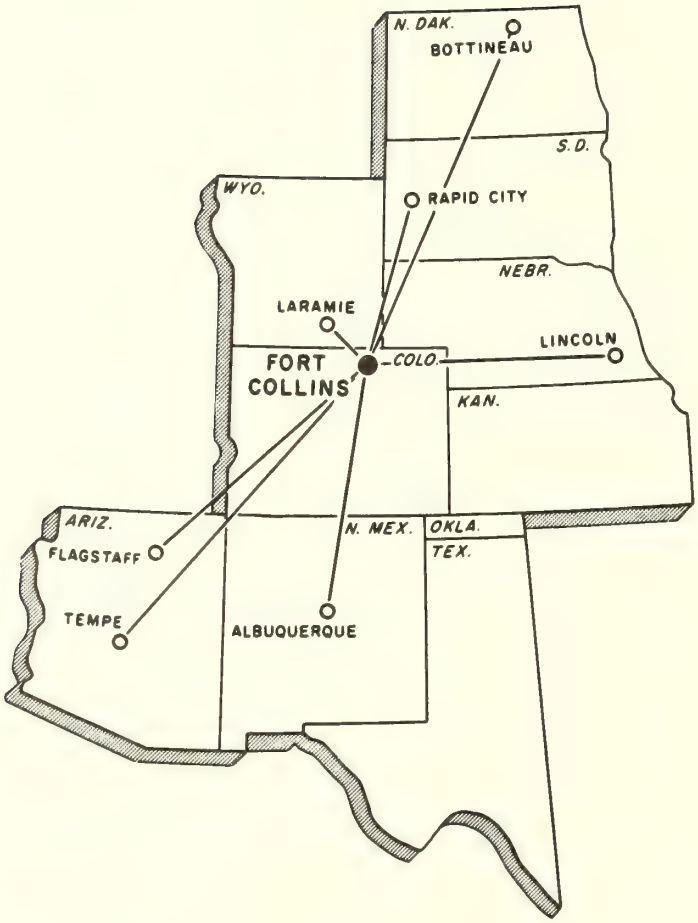
Hutchison, Boyd A. 1965. Snow accumulation and disappearance influenced by big sagebrush. U.S. For. Serv. Res. Note RM-46, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Sonder, Leslie W. and Harold P. Alley. 1961. Soil-moisture retention and snow-holding capacity as affected by the chemical control of big sagebrush (*Artemisia tridentata* Nutt.). Weeds 9:27-35.

Sturges, David L. 1975. Oversnow runoff events affect streamflow and water quality. p. 105-117. *In*: Snow Manage. on Great Plains Symp. Proc. Great Plains Agric. Counc. Publ. 73.

Sturges, David L. 1977. Soil moisture response to spraying big sagebrush: A seven-year study and literature interpretation. USDA For. Serv. Res. Pap. RM-188, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.


N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT
COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE

nber 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-349

OREST SERVICE
J.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Aquatic Inhabitants of a Mine Waste Stream in Arizona[1]

Michael Lewis[2]

Abstract

Changes in biotic composition and water quality in a copper mine waste stream were monitored before and after a large discharge of waste altered stream geomorphology and water quality. Initially, water quality and biotic composition in the waste stream were similar to those in a "control" stream; however, after the waste influx, biotic diversity was reduced and water quality was degraded.

Keywords: Water quality, aquatic habitat.

Arizona's copper mines require approximately 380,000 liters of water to process one ton of copper. The liquid wastes, which are often enriched with processing chemicals, metals, and suspended solids after passing through the refinement process, are stored in tailings ponds either for water storage, settling of suspended ore tailings, or control of discharges into public waters. Wastes as a result of seepage or discharge from such ponds often flow through flumes or natural drainages into nearby streams. Flow in these "waste streams" may be more constant than the natural flow in the receiving stream, which in Arizona is usually ephemeral or intermittent. Therefore, these waste streams, despite a degraded quality, may be capable of supporting aquatic organisms that are dependent upon a reliable surface flow for survival.

This Note reports the biotic composition of a waste stream, and changes in that composition due to an unusually large effluent release that had a degrading effect on the habitat.

[1]*The research reported here is a contribution of the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.*

[2]*Department of Zoology, Arizona State University, Tempe, Arizona. Administrative supervision was provided by Earl F. Aldon, project leader, Mine Spoil Reclamation in the Southwest, Rocky Mountain Forest and Range Experiment Station, Albuquerque, in cooperation with University of New Mexico. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Streams studied

The 1.87 km discharge channel studied conveyed effluents from a Pinto Valley Mine tailings pond into intermittent Pinto Creek (fig. 1). The mine and stream (33° 25' N; 111° 00' W) are located approximately 16 km west of Miami, Ariz. on the southeastern corner of the Tonto National Forest. The unshaded discharge channel flows through an area of crystalline intrusive rocks bordered by chapparal. Initially, the gravel-bottomed riffles alternated with pools with fine-grained bottoms. The stream was inundated, however, with an unusually large amount of ore tailings and waste water when the tailings pond dam ruptured in May 1975. The biotic composition and stream physiography were altered as a result.

Five sampling stations had been established 3 months prior to the dam rupture to determine biotic composition (fig. 1). Stations 1, 2, and 3, with a mean gradient of 5.25 cm/m, were located within 0.4 km of the tailings dam, while Stations 4 and 5, with a mean gradient of 0.75 cm/m, were located 1.3 km below the dam. All stations were affected by the effluents, and no control area in the stream could be established. As a result, the only reasonable basis of comparison was between the biota in the waste stream and that in Pinto Creek above their confluence.

Methods

The biota were sampled bimonthly at each sampling station from January 1975 to September 1976. Physiochemical observations were begun in January 1975. A pool and riffle area at each station in the discharge channel and Pinto Creek were qualitatively sampled for macroinvertebrates with a 4-mm mesh dip net and a Surber sampler[3] (0.09m²). Only qualitative evaluations are presented due to the difficulty of sampling the thick tailings cover over the substrate that persisted for most of the study. All macroscopic surface and clinging insects were brushed from rocks and benthic vegetation for preservation and later identification.

Fish were collected with portable shocking equipment and 6-mm mesh seines. The longfin dace, *Agosia chrysogaster,* was found to be the only existent species of fish in January 1975. A Petersen population estimate for the species was

[3]*The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

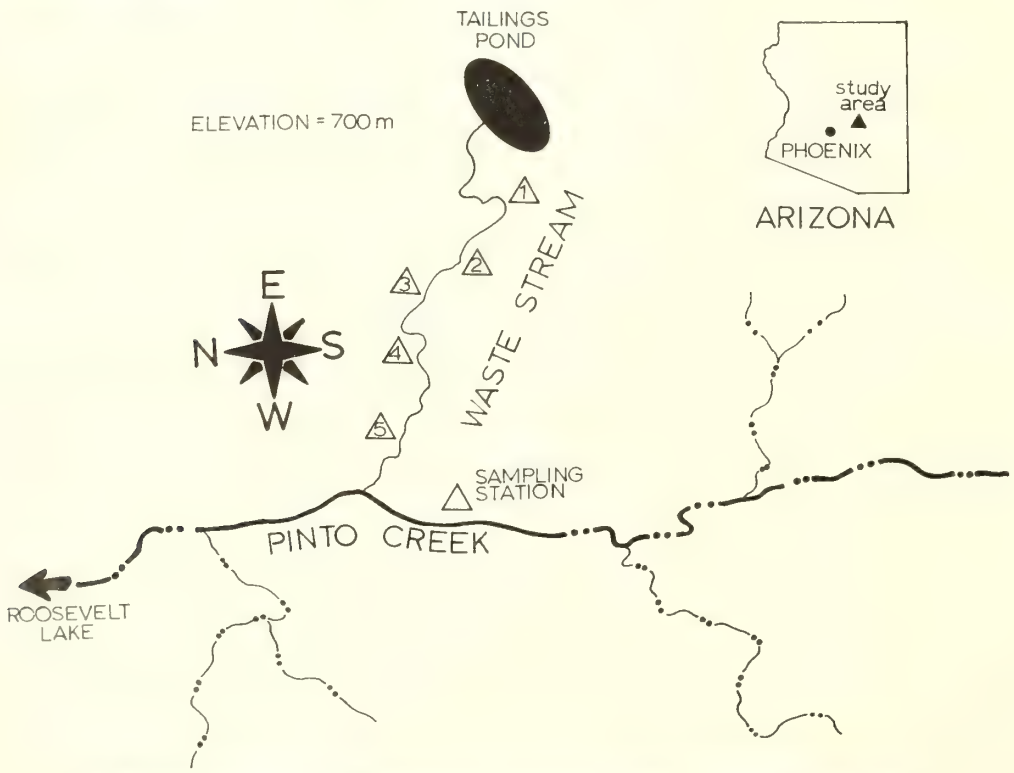


Figure 1.—Map location of the copper mine waste stream and sampling stations.

conducted during February 1975; two recovery periods were attempted within 1 month after clipping left pelvic fins.

Water samples were collected bimonthly at Station 5 and water quality was analyzed by the State Bureau of Water Quality Control. Chemical analyses, except metal content, followed procedures outlined in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1971). Metal content (total soluble metal) was determined with a flame spectrophotometer. Additional water samples taken monthly at Stations 1, 2, 3, and 4 were analyzed in the field for pH, hardness, copper, and iron using a Hach kit. Dissolved oxygen was measured by the modified Winkler method, and salinity, temperature, and conductivity with a YSI Model 33-SCT meter. Stream discharge was estimated following Robins and Crawford (1954).

Results

Water quality

High hardness and sulfates and low concentration of heavy metals and suspended solids characterized the effluents before the dam rupture (table 1). Most chemical quality parameters, except dissolved oxygen, water temperature, and pH, increased after the dam rupture but returned to predisturbance levels within 1 week. Low surface flow was continuous but variable (maximum, 8.7 l/s) during the study. Stream physiography and water quality of Pinto Creek was generally similar to that of the discharge channel before May and remained stable throughout the study.

Stream morphometry

Pool and riffle depths were reduced 50% to 90% respectively in May when the effluents (20 l/s) and ore tailings (suspended solids = 4,480 mg/l) innundated and buried the natural substrate (fig. 2). Natural substrate in pool and riffles was covered with ore tailings up to 0.5 m. As a result, the alternating pool-riffle structure with gravel substrate was permanently altered to essentially a long "run" with sandy substrate. Further, deposition of the tailings cemented the substrate by filling interstitial pore spaces and causing a shift of the stream channel within the flood plain. Summer rains scoured the deposits from the substrate and partially restored the stream bed at Stations 1, 2, and 3.

Biota

Two classes of vertebrates and eight orders (five genera) of aquatic invertebrates were found in the waste stream in March 1975, but only six orders (four genera) were collected in July of that year (table 2). Species of Baetidae, Helicopsychidae, Veliidae, Simulidae, and Notonectidae were most commonly collected prior to the tailings pond rupture but in July species of Gerridae, Hydrophilidae and Notonectidae predominated. The thick tailings deposits adversely affected the clinging species of Heptagenidae, Coenagrionidae and Helicopsychidae more than the bottom (Limnephilidae, Baetidae) and water surface (Gerridae, Veliidae) dwellers. Macroinvertebrate diversity was higher at Stations 1, 2, and 3 during the latter part of the study due to the scouring of tailings from the substrate.

Table 1.—Mean physiochemistry of tailings pond effluents in a waste stream for which biotic composition was determined during 1975

Quantity measured	1975						1976
	Jan.	Mar.	May	July	Sept.	Nov.	Jan.
pH	7.6	7.6	8.1	8.0	8.2	8.1	8.1
Calcium (Ca)	185	200	206	251	208	175	211
Magnesium (Mg)	21	24	24	32	22	26	12
Sodium (Na)	28	34	143	61	37	29	32
Iron (Fe)	<0.05	<0.05	0.25	0.1	<0.05	<0.05	<0.05
Copper (Cu)	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05
Manganese (Mn)	<0.05	<0.05	0.83	<0.05	<0.05	<0.05	<0.05
Zinc (Zn)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate (SO_4)	350	480	800	600	400	200	375
Total suspended solids	0	0	2,300	23	1	0	0
Total alkalinity (mg/l $CaCO_3$)	130	134	204	124	190	180	200
Total hardness (mg/l $CaCO_3$)	465	600	816	764	610	360	245
Mean discharge (l/s)	3.3	4.9	7.0	7.8	5.9	5.9	8.7

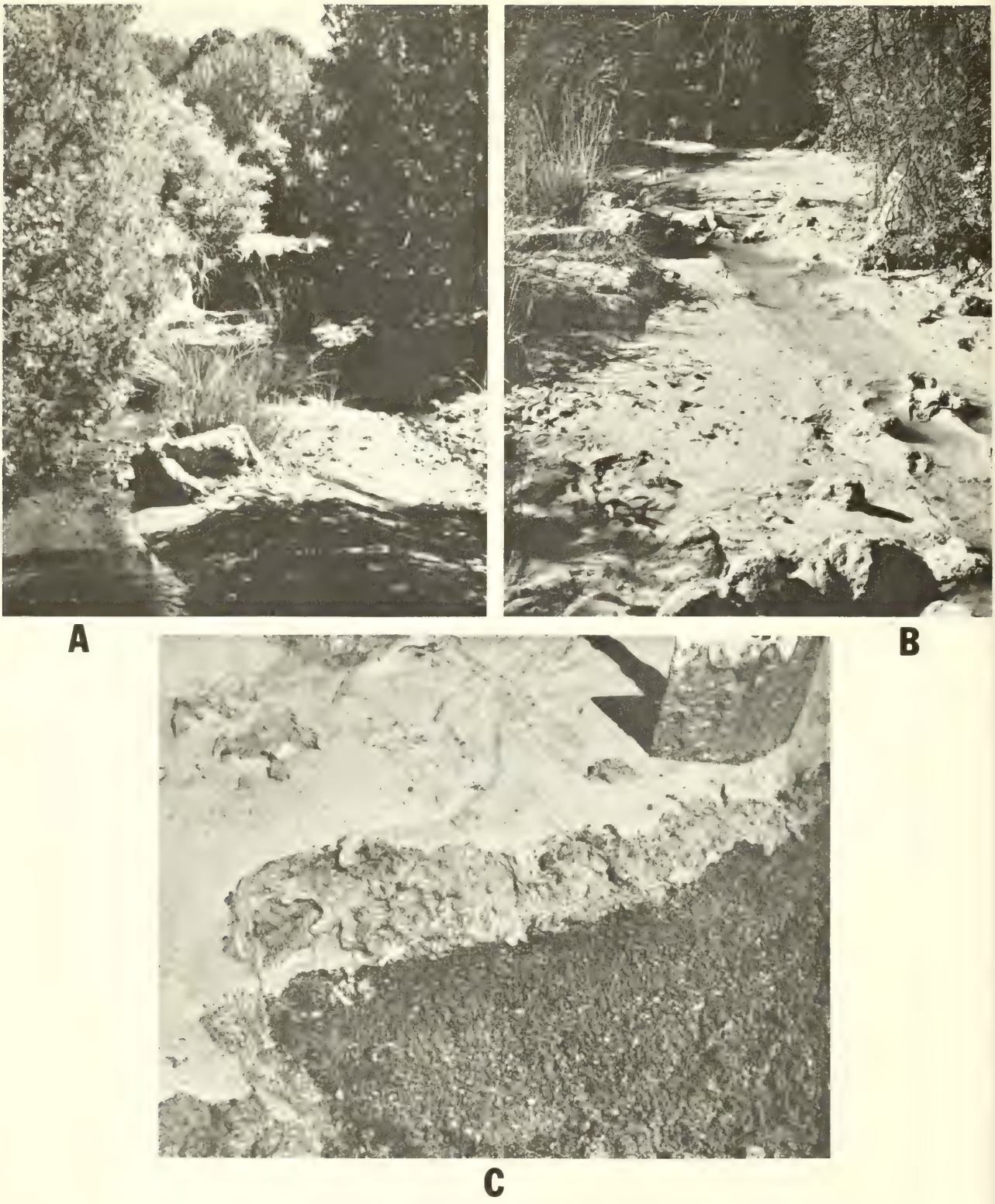


Figure 2.—Substrate of the waste stream before (A) and after (B,C) a large influx of tailings pond wastes.

Table 2.—Biotic composition in Pinto Creek (PC) and in the waste stream (WS) during three representative sampling periods

Taxa	March 1975		July 1975		March 1976	
	WS	PC	WS	PC	WS	PC
Gordiidae						
Gordius sp.	X	X		X		
Hemiptera						
Belostomatidae						
Abedus hebridi	X	X	X	X	X	X
Corrixidae						
Graptocorixa sp.	X	X		X		
Notonectidae						
Notonecta lobata	X	X	X	X	X	X
Notonecta kirbyi	X	X	X	X		X
Notonecta undulata		X		X	X	X
Gerridae						
Gerris remigis	X	X	X	X	X	X
Veliidae						
Rhagovelia sp.	X		X	X	X	X
Mesoveliidae						
Mesovelia mulsanti	X			X	X	X
Ephemeroptera						
Baetidae						
Callibaetis sp.		X		X		X
Baetis spp.	X	X	X	X	X	X
Heptagenidae						
Rhithrogena sp.				X	X	X
Lepidoptera						
Paragyractis sp.		X				X
Coleoptera						
Dytiscidae						
Agabus sp.	X			X		X
Thermonectes marmoratus	X			X		X
Dytiscus sp.	X			X		X
Gyrinidae						
Gyrinus sp.	X	X	X	X	X	X
Hydrophilidae						
Berosus sp.	X	X		X		X
Hydrophilus sp.		X		X	X	X
Diptera						
Culicidae						
Culex sp.	X	X				X
Tipulidae						
Tipulus sp.	X	X				X
Simuliidae						
Simulium sp.	X	X		X		
Tendipedidae						
Tendipes sp.	X	X	X	X	X	X
Tabanidae						
Tabanus sp.	X	X				
Trichoptera						
Limnephilidae						
Limnephilus sp.	X	X			X	X
Helicopsychidae						
Helicopsyche borealis	X	X		X		X
Odonata						
Lestidae						
Lestes cogener		X		X	X	X
Coenagrionidae						
Argia sp.		X		X		
Libellulidae						
Libellula sp.	X	X	X	X	X	X
Gomphidae						
Progomphus sp.	X	X		X		X
Megaloptera						
Corydalidae						
Corydalus cornutus	X	X		X		X

Rana and *Bufo* larva (frogs and toads) and approximately 158 *Agosia chrysogaster* (as determined from the population estimate) inhabited the waste stream before May, but were not collected again until July 1976. At this time surface flow in Pinto Creek near the confluence area was absent. Amphibian larva and *Agosia* were collected throughout the study in Pinto Creek. The number of genera in Pinto Creek was similar to that in the waste stream before May (table 3).

Benthic vegetation was more affected by the wastes than emergent vegetation or riparian species. The tailings deposits buried most benthic vegetative stands; however, partial emergence from the deposits occurred within 7 weeks after the waste influx. There was no discernible toxin damage to any plant species attributable to heavy metals.

Table 3.—Number of genera of invertebrates and vertebrates collected per sampling period in the waste stream and Pinto Creek

Sampling period	Waste stream	Pinto Creek
1975		
Jan.	11	14
March	24	25
May	4	24
July	9	26
Sept.	7	23
Nov.	9	20
1976		
Jan.	7	9
Feb.	8	13
March	14	26

Discussion

Streams polluted by heavy metals and suspended solids typically support less dense and diverse faunas than do unpolluted streams (Savage and Rabe 1973, Ryck 1974, LaBounty et al. 1975). Waste streams conveying undiluted metals and solids to a receiving stream would be expected to support fewer, if any, organisms. The waste stream in this report initially supported a fauna as diverse as that of the larger, less polluted Pinto Creek. However, after a large influx of wastes the biotic composition in the waste stream was reduced.

Changes in effluent quality were variable throughout the period of study and proper evaluation of the chemical factors on the biota was therefore difficult. Nevertheless, the drastic short term increases in suspended solids and the residual effects of the resultant siltation were markedly detrimental to the biota, more so than the increases in heavy metals. Suspended solids as high as 4,480 mg/l (mean = 2,300 mg/l) during the disturbance settled and quickly blanketed the stream bed and buried benthic vegetation and invertebrates. Flow at this time (20 l/s) and subsequently (<8 l/s) was inadequate to completely scour the deposits. As a result, biotic composition in the lower stream area 1 year after the dam rupture was approximately 42% less than that in March 1975. Suspended solids of 40 to 390 mg/l have been reported to reduce invertebrate populations by 25% to 85% (Tebo 1955, Gammon 1970), and inert deposits of only 2 cm have reduced dipteran populations by 50% (Hoak 1959).

The effects of the increases in heavy metals were less noticeable and more difficult to ascertain than those of the suspended solids. However, the short duration of the metals in the water column after the dam rupture, due to probable adsorption or complexing with organic and inorganic substances, may have reduced the toxicity of this pollution to the biota. Adsorption of metals by either muds or humic acids had been reported to reduce metal toxicity (Riemer and Toth 1970, Pagenkopf et al. 1974). In contrast, the insoluble complexed metal compounds, upon settling, served as a metal reservoir for bioaccumulation. Metal residues in invertebrates, aquatic vegetation, fish and sediments collected from the waste stream were significantly higher ($P<0.05$) than those in similar species collected from unpolluted streams (Lewis unpublished). The effect of these residues on biotic survival was not discernible, however with time it may become more noticeable.

Mean copper (0.1 mg/l) and manganese (0.83 mg/l) concentrations during the disturbance were below acute lethal levels estimated for juvenile *Agosia chrysogaster* in laboratory bioassays (0.88 mg/l copper and 130.0 mg/l manganese); however, the estimated safe copper level of 0.08 mg/l (based on an application factor of 0.01) was exceeded. Metal toxicity to invertebrates has been less investigated than that for fish but based on reported toxicity values it is unlikely that the metal ions in the wastes were acutely toxic. Rhewoldt et al. (1973) determined 96-hour lethal levels for damselflies (4.6-10.0 mg/l copper), caddisflies (6-12 mg/l) and midges (0.03-0.65 mg/l). Warnick and Bell (1969) observed mayflies and caddisflies to be resistant to 64 mg/l of copper and zinc.

Unpolluted desert streams support more diverse aquatic communities than do mine-polluted streams that are susceptible to ever-changing effluent quality and quantity. The ability of such "waste" streams to support permanent aquatic life with long life cycles is marginal. Therefore, the primary biological significance of these streams may be to serve as temporary habitat for larval amphibians, migratory invertebrates and

invertebrates with short aquatic life cycles. Finally, waste streams also support riparian communities; however, the permanence of these communities depends upon the potential toxicity of the metal-enriched sediments and water. The short duration of this study was inadequate to determine the presence of this toxicity.

Literature Cited

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th ed. New York, N.Y. 874 p.

Gammon, J. R. 1970. Effect of inorganic sediment on stream biota. U.S. Environ. Prot. Agency Rep. U.S. Gov. Print. Off., Wash., D.C. 119 p.

Hoak, R. D. 1959. Physical and chemical behavior of suspended solids. Sew. Ind. Wastes 31:1401-1408.

LaBounty, J., J. J. Satoris, L. D. Klein, E. F. Monk, and H. A. Salman. 1975. Assessment of heavy metals pollution in the upper Arkansas River of Colorado. Bur. of Rec. REC-ERC-75-5. Denver, Colo. 120 p.

Pagenkopf, G. K., R. C. Russo, and R. V. Thurston. 1974. Effects of complexation on toxicity of copper to fishes. J. Fish. Res. Bd. Canada 31:462-465.

Rehwoldt, R., L. Lasko, C. Shaw, and E. Wirhowski. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contam. Toxicol. 10:291-294.

Riemer, D. N., and S. J. Toth. 1970. Adsorption of copper by clay minerals, humic acids, and bottom muds. J. Amer. Water Works Assoc. 62:195-197.

Robins, C., and R. W. Crawford. 1954. A short accurate method for estimating the volume of stream flow. J. Wildl. Manage. 18:363-369.

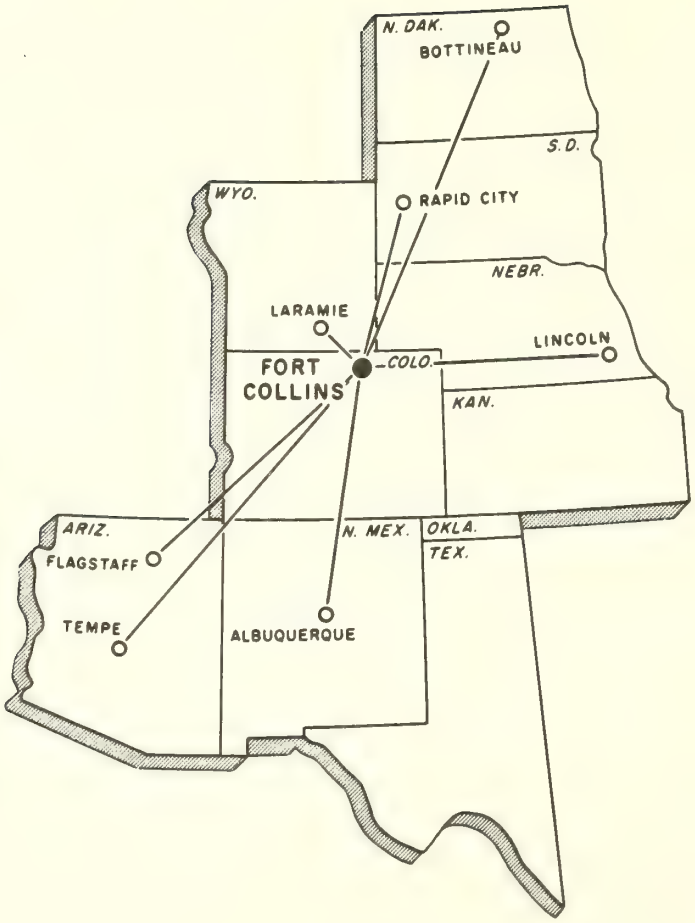
Ryck, F. 1974. Water quality survey of the Southeast Ozark mining area 1965-1971. Miss. Dep. of Conserv., Aq. Ser. No. 10. 28 p.

Savage, N. L., and F. N. Rabe. 1973. The effects of mine and domestic wastes on macroinvertebrate structure in Coeur d' Alene River. Northwest Sci. 47:159-167.

Tebo, L. B. 1955. Effects of siltation resulting from improper logging on the bottom fauna of a small trout stream in the southern Appalachians. Prog. Fish-Cult. 17:64-70.

Warnick, S. L., and H. L. Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Water Pollut. Cont. Fed. 4:280-285.

Agriculture—CSU, Fort Collins


N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE

ember 1977

USDA FOREST SERVICE
RESEARCH NOTE RM-350

OREST SERVICE
I.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Extending Service Intervals for Drum-type Meteorological Instruments

Kenneth G. Bird[1]

A simple method to extend the service interval of drum-type meteorological recording instruments to 44 days is presented. The chart resolution obtained with a weekly drum rotation is retained after conversion.

Keywords: Meteorological instrument servicing

Meteorological instrument servicing at remote study locations is costly and difficult. Monthly service visits are economically and logistically preferable. However, because of chart trace overlap between rotation periods, it is usually impossible to reduce information from drum-type recorders operated on a weekly rotation cycle when the instruments run for a month. The drive gears can be changed to a monthly rotation cycle, but most information about individual days is then sacrificed because of the compressed time scale.

A need existed to record solar radiation at the Stratton Sagebrush Hydrology Study area with the time resolution provided by a weekly rotation period, but at a monthly service interval. This note describes how two solar radiation recorders were modified to achieve the long service interval without sacrificing the resolution of an 8-day drum rotation. This method is equally applicable to other drum-type meteorological recorders.

[1]*Range Technician, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, with central headquarters maintained at Fort Collins in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Laramie, in cooperation with the University of Wyoming, and was supported in part by the Bureau of Land Management, U.S. Department of the Interior.*

Theory

Two instruments with battery-driven clocks must be used. Roller lever switches, triggered by notches in the chart drum, alternately turn the recorders on and off at 7.33-day intervals. The time offset is necessary to prevent one day's record from being recorded directly over the top of a previous day's record. The normal 8-day drum rotation period was reduced to 7.33 days by changing drive gears. The change in rotation period provided a 16-hour offset between recording periods that facilitated chart interpretation. After 44 days (three rotations of each recorder) the time scale of the first rotation is repeated, and the coincident graphs make chart reduction difficult.

The technique described is ideally suited to meteorological instruments recording cyclic data such as solar radiation, temperature, and humidity. Separation of the chart trace may be more difficult for noncyclic data.

Technical

The pyrheliometer modification required replacing the spring-driven clocks with electric

clocks and changing the gears to a 7.33-day rotation period. The next step in the conversion is to notch the flange on the bottom of the chart drums and install the roller level switches. To accomplish this, first position the drums on the recorders so that the pen tip is centered on the chart clip. Then turn the drums clockwise until the pen tip is 1 cm from the chart clip. Measure 1 cm clockwise from the chart clip (away from the pen) and mark the chart drum flanges. A notch slightly larger than the lever switch roller and two-thirds of the flange width must be cut in each drum at this mark using a small rat-tail file (fig. 1). It is important to keep the notches as narrow as possible, because both clocks will run when both rollers are in the notches simultaneously. This occurs at the end of each revolution of instrument No. 2, but lasts less than 10 minutes if the notches are slightly larger than the rollers.

Switch installation is critical. A subminiature roller lever switch is mounted on each instrument base so that the roller is located 0.5 cm counterclockwise of the notch when the pen is at the beginning of the chart (fig. 1). The roller on the switches must be vertically centered on the drum flange, and some shimming may be necessary to achieve the proper alignment. The roller arms are adjusted to open and close the switches only when actuated by the notches. The switches can be either glued or bolted to the instrument base after proper positioning.

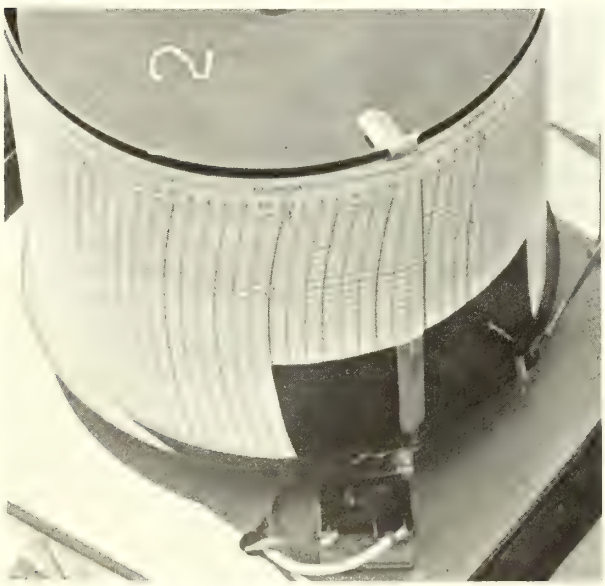


Figure 1.—Chart drums in start position showing position of notches in relation to chart clips.

The electrical wiring (fig. 2) was done with No. 22 stranded copper wire, and all connections were soldered. The battery pack was glued inside instrument No. 1 to protect it from the weather. To accomplish the wiring, drill one hole (approximately 0.5 cm in diameter) in the base of instrument No. 1 midway between the battery pack and the chart drum (fig. 3). In addition, also drill a hole in each instrument base 1 cm clockwise from the switch.

The clocks operate on 3 volts, with current supplied by two "D" cell batteries. Battery life will vary according to type of batteries used and operating temperatures. Alkaline cells have a longer life than zinc-carbon cells and should last 6 months even at cold temperatures.

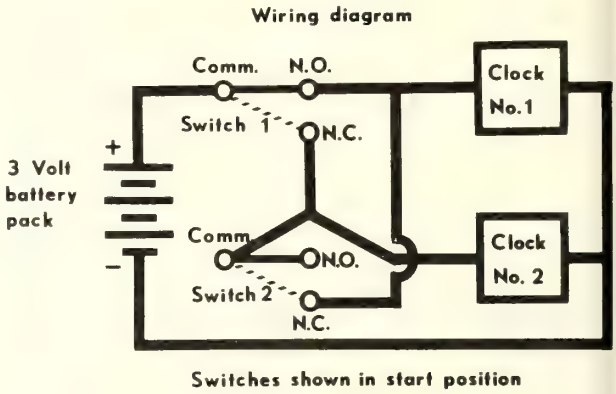


Figure 2.—Wiring diagram to alternately start and stop clock operation at 7.33-day intervals.

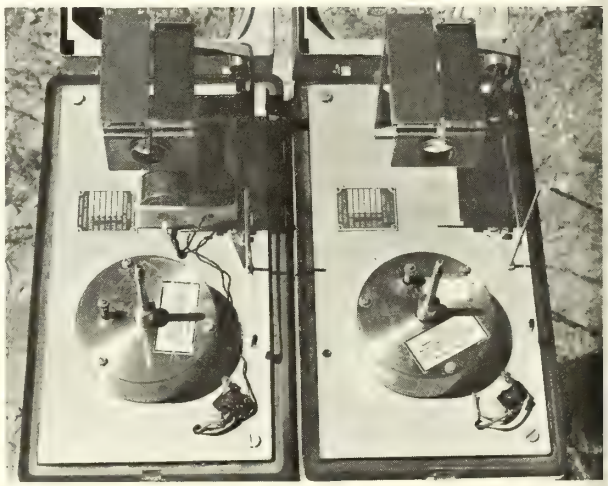


Figure 3.—Pyrheliometers after conversion for extended operation.

Meteorological instrument modification required approximately 3 hours. Exclusive of the two recorders, these items were used to convert the solar radiation recording system:[2]

1. Two electric chart drive clocks, Kingmann-White, model 301 @ $65.00 $130.00
2. Two, 15 x 110 gear drive sets for clocks, Kingmann-White, @ $7.50 15.00
3. Two subminiature roller level switches, Tandy Corp., No. 275-017, @ $1.19 2.38
4. Two bucket-type recording pens, Kingmann-White, Model 95, @ $1.50 3.00
5. One battery pack, Keystone Electronics, Model Number 176 .42
6. Two D cell alkaline batteries, @ $.67 1.34
7. Miscellaneous wire, solder, epoxy 1.00

Total $153.14

Chart Interpretation

Figure 4 shows a set of solar radiation charts containing 4 weeks of data. The vertical scale showing the intensity of radiation was not affected by conversion, but premarked time lines on the chart are no longer correct. The drums made one revolution in 7.33 days instead of 8 days, so that actual time intervals were 1.091 times longer than chart time intervals. New daily or hourly time lines must be marked on the chart, if time accuracy is required within a day. When this is a requirement, have charts printed with correct time lines.

A new instrument constant had to be calculated to use in converting the area under the chart trace to daily radiation input, because of the change in time scale. The constant was calculated by multiplying the manufacturer-supplied instrument constant by the ratio of the chart speed change:

$$\frac{7.333}{8} = 0.917;$$

0.917 x Old constant = Corrected constant

[2]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.*

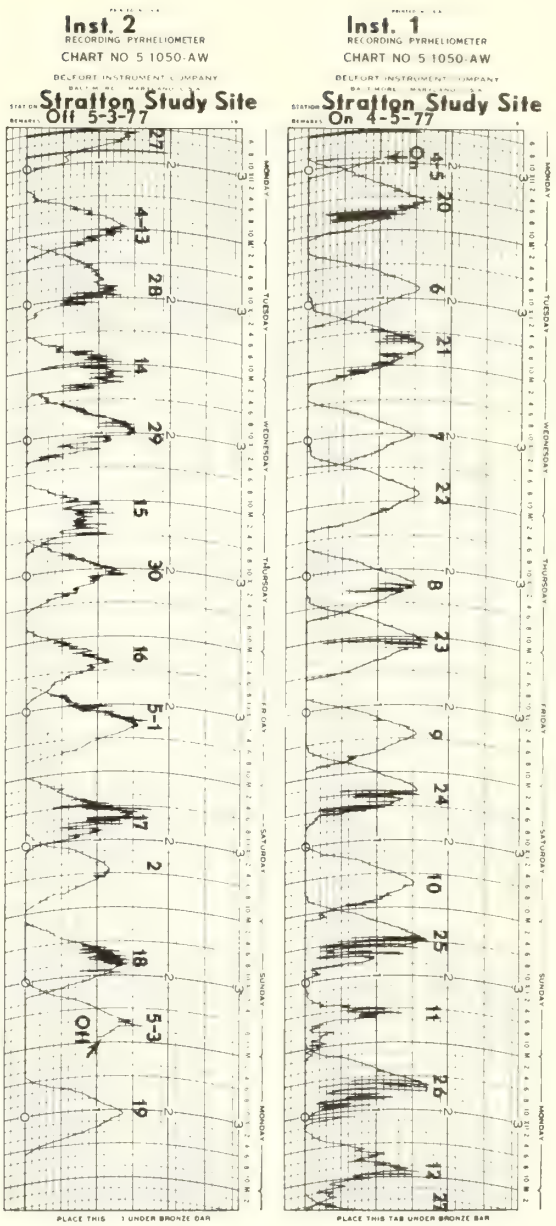


Figure 4.—Two solar radiation charts showing alternate operation over a 4-week period.

The data reduction procedure was not affected by the change in time scale when determining total radiation received each day. A planimeter was used to measure the area under the recorded trace in square centimeters. The daily planimeter reading in square centimeters was multiplied by the corrected instrument constant to determine the solar radiation input in Langleys. Computation of daily radiation totals did not require any adjustment in time lines since the chart trace returned to a constant base level each night.

ıber 1977

U S D A FOREST SERVICE
RESEARCH NOTE RM-351

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Past Diameters and Gross Volumes of Plains Cottonwood in Eastern Colorado

Carleton B. Edminster,[1] James R. Getter,[2] and Donna R. Story[2]

APR 10 19

Abstract

Bark thickness and past diameter relationships are developed for plains cottonwood in eastern Colorado. Tables of gross volume in cubic feet and point-sampling factors are presented for use in resource inventory.

Keywords: Forest measurement, tree volume tables, stand volume estimates, *Populus deltoides* var. *occidentalis*.

The increasing local demand for wood fiber and forest products has led to examination of forest resources along the South Platte and Arkansas Rivers and other streams in the eastern plains of Colorado. Bark thickness, past diameter, gross volume in cubic feet, and point-sampling relationships presented here were developed as part of a study of extensive inventory procedures applicable to plains cottonwood (*Populus deltoides* var. *occidentalis Rydb.*).

The cottonwood forest of the South Platte River basin in Morgan County was selected as the primary study area. This forest along the river bottom covers an area approximately 0.75 mile wide by 45.6 miles long. Orchards, shelterbelts, and ornamental plantings were excluded from the study.

Sample trees were measured by personnel of the Colorado State Forest Service.

[1]*Associate Mensurationist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 80521.*

[2]*Resource Inventory Forester and Research Technician, respectively, Colorado State Forest Service.*

Bark Thickness and Past Diameters

Past diameters of trees on temporary plots can be used to determine periodic changes in basal areas and volumes.

Diameter growth is the result of increase in thickness of both wood and bark. Both must be accounted for in relating present diameters outside bark to equivalent past diameters. Measurements of diameter outside bark and average periodic radial growth of wood are needed. Bark thickness often is not measured, since it can be estimated from relationships determined in advance.

The relationships presented below were computed from data obtained from 225 cottonwoods in the study area. Present diameters at breast height were measured to the nearest 0.1 inch with a diameter tape, and bark thickness was measured to the nearest 0.05 inch with a bark-measuring instrument at two points on each tree. Tree diameters ranged from 1.6 to 47.4 inches.

The following prediction equations relating diameter inside bark (d.i.b.) to diameter outside bark (d.o.b.) were computed by simple linear regression:

$$\text{d.i.b.} = -0.086 + 0.892\,(\text{d.o.b.}) \quad [1]$$
$$\text{d.o.b.} = 0.151 + 1.118\,(\text{d.i.b.}) \quad [2]$$
$$r = 0.998$$

Past d.i.b. may be expressed as a function of present d.o.b. by subtracting twice the radial wood growth (r.w.g.) from both sides of equation 1 as shown in equation 3:

$$\text{Past d.i.b.} = -0.086 + 0.892\,(\text{present d.o.b.} - 2.0\,(\text{r.w.g.}) \quad [3]$$

By substituting equation 3 into equation 2, the following equation for past d.o.b. can be derived:

$$\text{Past d.o.b.} = 0.055 + 0.996\,(\text{present d.o.b.}) - 2.235\,(\text{r.w.g.}) \quad [4]$$

Past diameters can then be computed directly using equation 4.

Gross Volume Table

Because little supervised cutting has been done in the cottonwood forests of eastern Colorado, the volume table presented here is based on measurement of standing trees. A Spiegel relascope was used to measure outside bark diameters at 4-foot intervals starting at the top of a hypothetical 0.5 foot stump up to a 2-inch-diameter top. These measurements were taken on the main stem and all major branches of each of 159 sampled trees. The d.i.b. relation (equation 1) was tested at points along the stem and branches of 10 trees to insure that the relation held for diameters measured at other than breast height. No discrepancies were found, so equation 1 was used to convert d.o.b. measurements to d.i.b.

Values presented in table 1 were computed from the regression equation:

$$\ln V = -6.5534 + 1.0636 \ln (D^2H) \quad [5]$$
$$r = 0.96$$

where: V = gross volume in cubic feet,
D = d.o.b. in inches at breast height,
H = total height in feet.

Diameters listed in table 1 are the midpoints of each 1-inch class, and heights listed are the midpoints of 10-foot classes. The block in table 1 indicates the extent of basic data.

Point-Sampling Factors

Point sampling factors expressed as volumes in cubic feet per square foot of basal area (B) were computed using the following equation derived from equation 5:

$$V/B = 0.2613\,(D^2H)^{1.0636}/D^2$$

Values given in table 2 for combinations of measured tree diameter and height can then be used in efficient point-sample cruising for volume.[3] Volume per acre is computed as follows:

1. Multiply the number of trees counted through the prism or relascope in each diameter-height class by the class point-sampling factor given in table 2.
2. Sum the results of step one.
3. Multiply this total by the basal area factor of the prism or angle gage used and divide by the number of points sampled in the stand.

Time and effort can often be saved if only height of counted trees are measured, while diameters are estimated by broad diameter classes. This savings is possible because volume per square foot of basal area does not vary greatly among trees in a single height class in table 2.

[3]*Myers, Clifford A., and Carleton B. Edminster. 1972. Volume tables and point-sampling factors for Engelmann spruce in Colorado and Wyoming. USDA For. Serv. Res. Pap. RM-95, 23 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

Table 1.--Gross volumes in cubic feet inside bark for plains cottonwood in eastern Colorado.

Diameter breast height outside bark	Total height in feet								Basis no. trees
	10	20	30	40	50	60	70	80	
Inches	Volume in cubic feet								
5	.51	1.06	1.63						3
6	.75	1.56	2.40	3.26					5
7	1.04	2.16	3.33	4.52	5.74	6.96			9
8	1.38	2.88	4.43	6.01	7.62	9.25	10.90		14
9	1.77	3.69	5.69	7.72	9.79	11.89	14.00		7
10		4.62	7.12	9.66	12.25	14.87	17.52		7
11		5.66	8.72	11.83	15.00	18.22	21.46		11
12		6.81	10.49	14.24	18.06	21.92	25.83		2
13		8.08	12.43	16.88	21.41	25.99	30.62		8
14		9.46	14.56	19.77	25.06	30.43	35.85		13
15		10.95	16.86	22.89	29.02	35.24	41.51		4
16		12.56	19.34	26.26	33.30	40.42	47.62	54.89	14
17		14.29	22.00	29.88	37.88	45.99	54.18	62.45	4
18		16.14	24.85	33.74	42.78	51.93	61.18	70.52	8
19		18.11	27.87	37.85	47.99	58.26	68.64	79.12	7
20		20.20	31.09	42.22	53.52	64.98	76.55	88.24	8
21		22.41	34.49	46.83	59.38	72.08	84.93	97.89	8
22		24.74	38.07	51.70	65.55	79.58	93.76	108.07	2
23		27.19	41.85	56.83	72.05	87.47	103.06	118.79	4
24		29.77	45.82	62.22	78.88	95.76	112.82	130.04	3
25		32.47	49.97	67.86	86.04	104.45	123.06	141.84	2
26		35.29	54.32	73.77	93.53	113.54	133.77	154.18	5
27			58.86	79.93	101.34	123.03	144.95	167.07	1
28			63.60	86.36	109.49	132.93	156.61	180.51	2
29				93.05	117.98	143.23	168.75	194.50	0
30				100.01	126.80	153.94	181.37	209.04	1
31				107.24	135.96	165.06	194.47	224.15	0
32				114.73	145.46	176.59	208.06	239.81	0
33				122.49	155.30	188.54	222.13	256.03	2
34				130.52	165.49	200.90	236.69	272.82	0
35				138.83	176.01	213.68	251.75	290.17	1
36				147.40	186.88	226.88	267.30	308.09	0
37				156.24	198.10	240.49	283.34	326.58	3
38				165.36	209.66	254.53	299.88	345.64	1
39						268.99	316.91	365.28	0
40						283.87	334.45	385.49	0
Basis no. trees	3	13	29	47	38	23	6	0	159

Derived from: $\ln V = -6.5534 + 1.0636 \ln (D^2H)$

Merchantable stem (excluding 0.5-foot stump) and branches to 2-inch diameter.

Diameters listed are midpoints of 1-inch classes.

Heights listed are midpoints of 10-feet classes.

Block indicates extent of basic data.

Table 2.--Gross volumes in cubic feet per square foot of basal area for plains cottonwood in eastern Colorado.

Diameter breast height outside bark	Total height in feet							
	10	20	30	40	50	60	70	80
Inches	-Cubic feet-							
5	3.7	7.8	11.9					
6	3.8	7.9	12.2	16.6				
7	3.9	8.1	12.5	16.9	21.5	26.1		
8	3.9	8.2	12.7	17.2	21.8	26.5	31.2	
9	4.0	8.4	12.9	17.5	22.2	26.9	31.7	
10		8.5	13.1	17.7	22.5	27.3	32.1	
11		8.6	13.2	17.9	22.7	27.6	32.5	
12		8.7	13.3	18.1	23.0	27.9	32.9	
13		8.8	13.5	18.3	23.2	28.2	33.2	
14		8.8	13.6	18.5	23.4	28.5	33.5	
15		8.9	13.7	18.7	23.6	28.7	33.8	
16		9.0	13.8	18.8	23.8	28.9	34.1	39.3
17		9.1	14.0	18.9	24.0	29.2	34.4	39.6
18		9.1	14.1	19.1	24.2	29.4	34.6	39.9
19		9.2	14.2	19.2	24.4	29.6	34.9	40.2
20		9.3	14.2	19.3	24.5	29.8	35.1	40.4
21		9.3	14.3	19.5	24.7	30.0	35.3	40.7
22		9.4	14.4	19.6	24.8	30.1	35.5	40.9
23		9.4	14.5	19.7	25.0	30.3	35.7	41.2
24		9.5	14.6	19.8	25.1	30.5	35.9	41.4
25		9.5	14.7	19.9	25.2	30.6	36.1	41.6
26		9.6	14.7	20.0	25.4	30.8	36.3	41.8
27			14.8	20.1	25.5	30.9	36.4	42.0
28			14.9	20.2	25.6	31.1	36.6	42.2
29				20.3	25.7	31.2	36.8	42.4
30				20.4	25.8	31.4	36.9	42.6
31				20.5	25.9	31.5	37.1	42.8
32				20.5	26.0	31.6	37.2	42.9
33				20.6	26.1	31.7	37.4	43.1
34				20.7	26.2	31.9	37.5	43.3
35				20.8	26.3	32.0	37.7	43.4
36				20.8	26.4	32.1	37.8	43.6
37				20.9	26.5	32.2	37.9	43.7
38				21.0	26.6	32.3	38.1	43.9
39						32.4	38.2	44.0
40						32.5	38.3	44.2

Derived from: $V/B = 0.2613 (D^2 H)^{1.0636} / D^2$

Diameters listed are midpoints of 1-inch classes.

Heights listed are midpoints of 10-feet classes.

uary 1978

U S D A FOREST SERVICE
RESEARCH NOTE RM-352

OREST SERVICE
I.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

First Bald Eagle Eggs Collected for Analysis in Arizona

Teryl G. Grubb[1] and Duane M. Rubink[2]

Abstract

In 1977 two cold eggs, 27 days developed, were taken from a fallen nest and a third was retrieved from a nest abandoned after unsuccessful incubation. Eggshells were 7-15% thinner than pre-DDT norms, but pesticide levels appeared too low to cause reproductive problems.

Keywords: *Haliaeetus leucocephalus leucocephalus*, eggs, pesticide levels.

The presence of nesting Southern Bald Eagles (*Haliaeetus leucocephalus leucocephalus*) in Arizona has long been documented (Bent 1937, Mearns 1890); however the breeding population is relatively small (Rubink and Podborny 1975), with only eight occupied territories known in 1977. As a result, descriptive information on Bald Eagle eggs has been lacking for Arizona until now. The eggs described in this report are the first collected for analysis in the State.

Egg Collection

Eggs A and B were recovered from a fallen eyrie north of Phoenix. The nest had been built about 35-40 feet above the ground in a dead, leaning cottonwood (*Populus fremontii*). Normal incubation was last observed on February 16, 1977. On March 1, the fallen tree was discovered; it had probably blown down during high winds of the previous week. The nest remained intact and nearly upright in its supporting branches on the ground.

The cold eggs were buried under several inches of nest lining and were not visible until some of the lining was removed. Evidently an adult had buried the eggs prior to the fall; or the mishap occurred when both the birds were off the nest, in which case they may have concealed the eggs before leaving. Later analysis showed the eggs to be about 27 days developed when the nest fell. Although both adults were present in the territory when the eggs were recovered, they showed no particular attachment to the specific site nor any special alarm at the intrusion. Subsequent observations through May 1 failed to show any evidence of a renesting attempt.

Egg C came from an eyrie near the town of Camp Verde. Incubation was first observed at this cliff site on March 1, 1977. The following week local biologists saw on egg from the cliff above. When incubation exceeded the usual 35 days and continued well into April, the nest was checked two or three times per week from a safe vantage point across the river.

On May 4, the incubating bird was noticeably restless, changing position more often and standing at the nest edge longer than usual. By May 6, after nearly 10

[1] *Wildlife biologist, Rocky Mountain Forest and Range Experiment Station, located at Tempe, in cooperation with Arizona State University. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *State supervisor, Division of Wildlife Service, U.S. Fish and Wildlife Service, Phoenix, Ariz.*

weeks of incubation, the eagles had abandoned the nest. They were observed only once that day as they flew down the canyon without stopping at the eyrie. The birds were also absent the next day when the egg was collected. It showed no signs of development although its exterior surface was polished from the long incubation.

Measurement and Analysis

All three eggs were sent to the U.S. Fish and Wildlife Service Wildlife Research Center at Patuxent, Md. for analysis (tables 1 and 2). There are no data on pre-1946 (pre-DDT) shell thickness norms for Arizona. However, the figure for Bald Eagle eggs from Florida is 0.584 mm; from Texas and Louisiana, 0.6032 mm; and from California and Baja, 0.5836 mm (Anderson and Hickey 1972, D. W. Anderson, unpubl. data). Depending upon which of these figures is used for comparison, eggshells A and B appear 10-15% thinner than pre-1946 norms, while C may be reduced by about 7-10%.

The levels of all chemical residues found were low, except for the moderate concentration of DDE. Although these levels of DDE could account for the eggshell thinning, they do not seem high enough to cause reproductive problems (Krantz et al. 1970; Wiemeyer et al. 1972). Slightly higher levels of most compounds in egg C may be a result of the nest location less than 4 miles downstream from heavy agricultural activity; however, none of these levels appear sufficient to have caused the egg's failure.

Table 1.—Physical measurements of three Bald Eagle eggs recovered from two Arizona eyries along the Verde River in 1977.

Characteristics	Egg			Average
	A	B	C	
Length (*mm*)	72.1	70.1	69.2	70.5
Breadth (*mm*)	52.9	53.8	54.9	53.9
Estimated volume (*cc*)	107.0	105.0	106.0	106.0
Total weight (*g*)	89.41	92.98	77.99	—
Shell thickness (*mm*)	0.513	0.525	0.54	0.526
Development (*days*)	27.0	27.0	0.0	—

Table 2.—Results of chemical analyses on three Bald Eagle eggs recovered from two Arizona eyries along the Verde River in 1977. (ppm corrected wet weight; lower limit of detection is 0.05 ppm, prior to correction for dehydration. "-" indicates not detected.)

Compound	Egg		
	A	B	C
p,p'-DDE	6.8	9.0	4.9
p,p'-DDD	0.14	0.11	0.13
p,p'-DDT	—	—	—
Dieldrin	0.13	0.14	0.20
Heptachlor epoxide	—	—	—
Oxychlordane	—	—	—
cis-Chlordane	0.06	0.07	0.09
cis-Nonachlor	0.04	0.05	0.07
trans-Nonachlor	0.15	0.11	0.21
Endrin	—	—	—
Est. Toxaphene	—	—	0.04
HCB	—	—	—
Mirex	—	—	—
Est. PCB	1.2	1.7	8.5

Acknowledgements

The authors gratefully acknowledge Bill Britton, Wildlife Biologist, Prescott National Forest, for his assistance in the extended surveillance of the Camp Verde nest; and the Patuxent Wildlife Research Center for providing the measurements and chemical analyses reported herein.

Literature Cited

Anderson, D. W. and J. J. Hickey. 1972. Egg shell changes in certain North American birds. Proc. 15th Inter. Ornithol. Congr.: 514-540.

Bent, A. C. 1937. Life histories of North American birds of prey. Part 1. U.S. Nat. Mus. Bull. 167. 409 p.

Krantz, W. C., B. M. Mulhern, G. E. Bagley, A. Sprunt, F. J. Ligas, and W. B. Robertson. 1970. Organochlorines and heavy metal residues in bald eagle eggs. Pestic. Monit. J. 4(3):136-410.

Mearns, E. A. 1890. Observations on the avifauna of portions of Arizona. Auk 7:45-55.

Rubink, D. M. and K. Podborny. 1975. The southern bald eagle in Arizona. Endangered Species Rep. 1. U.S. Fish & Wildl. Serv., Albuquerque, N. Mex. 33 p.

Wiemeyer, S. N., B. M. Mulhern, F. J. Ligas, R. J. Hensel, J. E. Mathisen, F. C. Robards and S. Postupalsky. 1972. Residues of organochlorine pesticides, polychlorinated byphenyls, and mercury in bald eagle eggs, and changes in shell thickness. Pestic. Monit. J. 6(1):50-55.

3. 79: RM-353

uary 1978

RESEARCH NOTE RM-353

OREST SERVICE
I.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Abert Squirrels Influence Nutrient Transfer through Litterfall in a Ponderosa Pine Forest[1]

T. H. Skinner and J. O. Klemmedson[2]

Abstract

Study objective was to determine the influence of Abert squirrels on transfer of nutrients, specifically nitrogen and carbon, from trees to the forest floor. Increase in total N and C in litterfall because of squirrel activities was associated primarily with the increase in total mass of litterfall. Abert squirrels made their most significant contribution to the nutrient transfer process through clipped twigs which had an N concentration nearly double that of "natural" litterfall.

Keywords: *Sciurus aberti*, litterfall, nutrient transfer.

In this paper we report results of a combined study of Abert squirrels (*Sciurus aberti*) and the nutrient regime. Nutrients are frequently a limiting factor in forest ecosystems, and are usually influential in ecosystem productivity. Animal life has been studied extensively in terms of its contribution to decomposition processes in the nutrient cycle, but has been virtually forgotten with respect to the restitution phase, especially litterfall. Animals may play an important role in this part of the nutrient cycle. The objective of this study was to determine the influence of the Abert squirrel on transfer of nutrients, specifically nitrogen (N) and carbon (C), from trees to the forest floor.

Methods

Field studies were conducted in the vicinity of Fort Valley Experimental Forest, near Flagstaff, Ariz. The study site was characterized by an open stand of large pole and small saw timber ponderosa pine with little understory vegetation on rolling slopes (fig. 1). Soils were derived from basalt and appeared to be of the Brolliar Series. An area of about 9.2 hectares was searched to locate and tag all squirrel nest and "feed" trees. Feed trees were defined as trees in which squirrels exhibited medium to heavy feeding activity. A total of 43 feed trees and 27 nest trees were found. Fourteen of each were selected at random for study. In addition, 14 control trees were randomly selected from a pool of 30 trees; these trees were similar to the nest and feed trees but showed no evidence of squirrel use.

A two-stage sampling system was used. Litter traps (50 cm x 50 cm) made of 1/8-inch hardware cloth (Davis et al. 1968) were located at random in the "tree influence zone" of each of the 42 trees for periodic collections. The tree influence zone was the

[1]*Research reported here was funded jointly by the Rocky Mountain Forest and Range Experiment Station and the McIntire-Stennis Cooperative Forestry Research Program. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Supervision was provided by David R. Patton, project leader for Wildlife Habitat Research at the Station's Forestry Sciences Laboratory in Tempe, Arizona.*

[2]*Range Conservationist, Bureau of Land Management, Ely, Nev. and Professor, School of Renewable Natural Resources, Univ. of Ariz., Tucson, respectively.*

Figure 1.—The study site was characterized by an open stand of large pole and small saw timber pine with little understory vegetation.

area directly under the canopy but extending one meter beyond its projected perimeter. These influence zones were delineated on the ground, and a sufficient number of traps placed under trees to cover 10% of the zone (average number of traps was 10 per tree).

In addition to litter sampled with traps, all litter known to have fallen to the forest floor because of squirrel activity was collected by hand from outside the litter traps but within the tree influence zone. This sample was collected to permit a more adequate estimate of major litter transfer by squirrels. The traps provided a check on the "hand" sampling, an estimate of the difference between control, nest, and feed trees, and a measure of small litter transfer by the squirrel (material that could not be detected without the aid of a trap).

Litter was collected between the 22nd and 25th of August, September, November, January, April, May, and July of 1974-75. Because of the variable interval between sampling dates, litterfall data were expressed on a monthly basis for comparison and statistical analyses.

Trap collections under a single tree were pooled by date and separated according to needles, bark and twigs (≤1 cm in diameter), cones (including bracts and seeds), and "other" components (including twigs clipped by squirrels, peeled twigs, mistletoe, nest parts, and fallen twig ends). Needled twig ends lost from the forest canopy because of natural causes such as wind or storms were defined as fallen twig ends and were distinguished from squirrel clippings by the absence of easily identifiable teeth marks from the squirrel's bite (Rasmussen et al. 1975). Nests were taken apart and separated into twigs, needles, grass, and other material. Samples were oven dried at 70°C, weighed, and ground to pass a 40-mesh screen. The material was then analyzed for total nitrogen by the salicylic acid modification of the Kjeldahl procedure (Bremner 1965) and organic carbon by dry combustion using a high-frequency induction furnace (Allison et al. 1965).

T-tests were used to test hypotheses of no differences between treatment means.

Results

At the end of the field study, sample trees were reexamined as to the accuracy of the presampling tree classification. Of the 14 trees classified as feed trees at the outset of the study, only 6 were used as feed trees during the study.[3] Of the 14 nest trees, which also served to some extent as feed trees in 1973-74, only 8 were fed upon (6 heavily) in 1974-75. The control trees, with one exception, again were not used by squirrels during the field study.

To accomplish the objectives of the study, it was necessary to reclassify the sample trees in accordance with the actual use by squirrels during the sampling period. Because litterfall of nest and feed trees was similar, and because many nest trees served also as feed trees, the nest tree classification was dropped and sites were reexamined on the basis of feeding activity alone. Comparison revealed no differences in physical characteristics between the 13 established feed trees and the 13 remaining control trees.

Composition and Amount of Litterfall

The effects of Abert squirrels on the amount and distribution of litterfall from feed trees are summarized in table 1. Total litterfall from feed trees was 90 $g/m^2/yr$ greater (50% more) than that from control trees, and the increase by components ranged from 25% for needles to 28 times for "other" litterfall; the latter category was increased from 1 $g/m^2/yr$ for control trees to 32 $g/m^2/yr$ for feed trees. On a yearly basis only conefall was unaffected by squirrels.

Needlefall averaged 181 $g/m^2/yr$ for control and feed trees, or about 76% of total litterfall. The latter figure is comparable to other forests (Bray and Gorham 1964, Rodin and Bazilevich 1967). Needles made up more than 90% of litterfall from September through November, the peak period for litterfall for pine forests (Bray and Gorham 1964, Stark 1973). In only one period, June-July, did another litterfall component (bark and twigs) outweigh needles. Needles were mostly old and dry, except during early

[3] *According to D. R. Patton (personal communication), there is now some evidence that Abert squirrels rotate their use of trees for feeding from year to year.*

Table 1.—Average amount of dry matter in litterfall for the year and distribution among components for control and feed trees

Component of litterfall	Control trees		Feed trees		Pooled st'd error	Significance of t-test[1]
	$g/m^2/yr$	%	$g/m^2/yr$	%		
Needles	161.1	81.8	200.9	70.0	16.7	.05
Bark and twigs	28.5	14.5	41.8	14.6	5.6	.05
Cones	6.4	3.2	12.1	4.2	5.1	n.s.
Other	1.1	.05	32.1	11.2	10.3	.01
Total litterfall	197.1	100.0	286.9	100.0	24.4	.01

[1]0.05 level of probability.

spring when many green needles were found in litterfall. Periodic snow storms and increased squirrel activity are probably associated with fall of green needles in spring.

Litterfall from feed trees contained 13 $g/m^2/yr$ more bark and twigs than from control trees (table 1), but the proportion of bark and twigs in litterfall was unchanged at 14.5%. Except for the later winter period for feed trees and the June-July period, bark and twigs were the second most abundant litterfall category. In most cases, bark and twig litterfall appeared old and dry.

Cone litterfall consisted of mature cones that fell from trees after seed dispersal, a few immature ovulate cones still tightly closed, the small but numerous staminate cones in early summer, and various cone parts (seeds, seed wings, and scales). Cones accounted for only 3.8% of all litterfall trapped, and this consisted primarily of old cone bracts.

Chewed cones (cones from which bracts and seeds had been removed) also were found in litterfall, particularly during late summer and fall (July-November). During the study, chewed cone material accounted for only a small part of squirrel-activated litterfall, but this percentage could increase (or decrease) with the variable production of cones. In 1974-75, only one of the 26 trees—a feed tree—was used heavily by squirrels for cone feeding.

Mistletoe was a minor but consistent component of "other" litterfall. Other litterfall common to both feed and control sites was "fallen twig ends".

Clipped twigs, by definition, were found only under feed trees (fig. 2). The number of clipped twigs collected per tree annually ranged from 6 to 118; the total number of twigs clipped during the year for all 31 feed trees was 392. The average weight of a clipped twig was approximately 10 grams, about 80% needles and 20% wood and bark. Clipped twigs were young and frequently had drops of recent sap flow at the clipped end. Attached needles were green and fresh. Clipped twigs were frequently accompanied by peeled twigs (fig. 3) whose inner and outer bark had been removed. On occasion, chewed outer bark, which gave every appearance of having been peeled from a twig, also was found in litterfall.

If the weight of needles from clipped twigs (22 g/m^2) and the weight of wood and bark from clipped twigs and peeled twigs (6.9 g/m^2) are added to the weight of needles and bark and twigs for feed trees shown in table 1, the overall influence of squirrel activity on these two dominant categories of litterfall can be calculated. This total added figure for needlefall is 222.9 $g/m^2/yr$, or a 39% increase over that of the control trees; the total for bark and twigs is 48.7 $g/m^2/yr$ or a 71% increase over the control.

Figure 2.—Ponderosa pine twigs clipped by Abert squirrels.

Figure 3.—Ponderosa pine twigs peeled by Abert squirrels.

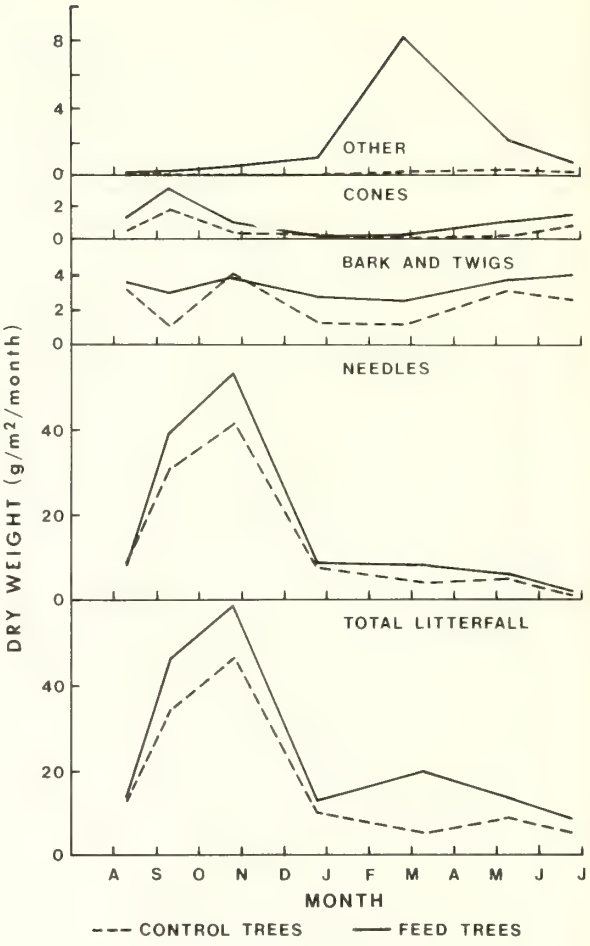


Figure 4.—Dry weight per month of litterfall from feed and control trees for seven collection periods.

Nest parts were a third component of litterfall occasionally found under feed-nest trees. This duff-like material was a loose mixture of bits of grass, shredded bark, and needles all packed together. Where nest duff was a part of litterfall, the nests appeared to be in good shape and not in a state of decay. However, it was very difficult to determine by appearance alone whether or not a nest was being used currently by squirrels. Presence of squirrel clippings under a nest tree may be solely the result of feeding activity.

During late winter (February-April) significantly greater amounts of needle, bark, and twig litterfall were found under feed than control trees (fig. 4). The sum of cone, needle, bark, and twig components as well as total litterfall (including "other"), was also greater under feed trees. The only other significant difference was in June and July when needlefall from feed trees was greater than from control trees.

During the February-April period, when differences between feed and control trees were noted in most litterfall components, the weight of "other" litterfall also reached a peak (fig. 4). Other components comprised more than 40% of litterfall of feed trees during this period, but accounted for only 2.3% of the litterfall of control trees. Although squirrels clipped twigs throughout the year (table 2), the greatest amount of clipping took place during the winter, a phenomenon reported by other observers (Pearson 1950, Keith 1956, Stephenson 1975). Of all "other" components, clipped and peeled twigs accounted for 94% of the weight (89% clipped twigs, 5% peeled twigs); mistletoe, fallen twig ends, and nest duff accounted for the rest. Under control trees, "other" litterfall contained only mistletoe and fallen twigs, the latter accounting for the major part (64.6%).

Table 2.—Number of clipped twigs (trapped and untrapped) found in the tree influence zone of feed trees for each collection period

Collection period	Months	Number of clipped twigs
July-Aug.	1	1
Aug.-Sept.	1	20
Sept.-Nov.	2	29
Nov.-Jan.	2	36
Jan.-Apr.	3	257
Apr.-May	1	22
May-July	2	27

Nutrient Content

Concentration of Nitrogen and Carbon

With the exception of cone material, no significant differences in percentage N of litterfall components common to both feed and control trees were found for any of the collection periods (fig. 5). Percentage N of cone litterfall under control trees was higher than that of feed trees in May. As percentage N of cone material from feed trees declined from October to May, percentage N of cone material of control trees increased (fig. 5). Cone litterfall of feed trees was found to contain fewer seeds and more bracts than that of control trees. Because seeds had higher N content than chewed cones or bracts, the presence of more seeds in cone material under control trees may help explain the higher N concentration of cone litterfall from control trees.

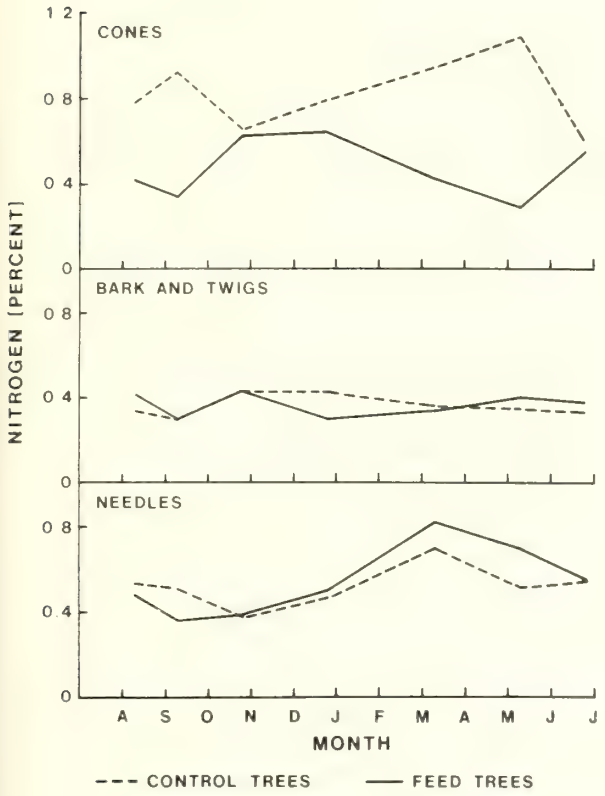


Figure 5.—Percentage nitrogen of needle, bark and twig, and cone components of litterfall for feed and control trees for seven collection periods.

The seasonal trend in N concentration of needle litterfall was similar for both treatments (fig. 5). Nitrogen concentration was highest during late winter and early spring (February-April) and lowest in fall and early winter. Nitrogen concentration in needles from clipped twigs was consistently higher than that of natural needlefall for all collection periods. Over the year, needles of clipped twigs averaged 1.13% N versus only 0.57% N in naturally cast needles. The N percentage of twigs and bark from clipped twigs also was greater than that of "natural" litterfall (0.60% versus 0.37%).

Nitrogen is a mobile element associated with areas of new tissue growth (Kramer and Kozlowski 1960). A gradation in N concentration was noted within clipped twigs from the clipped end to the terminal bud.[4] Percentage N was 1.4% in the terminal bud, 1.1% within the next half-inch and only 0.4% in the half-inch just above the point of clipping. Although the parts of the tree selected by squirrels for their food are among the highest in N concentration, we have no basis for saying that squirrels select food on the basis of N content.

The component of natural litterfall most comparable to clipped twigs is fallen twig ends. These needled twigs were found under both feed and control trees. Needles of fallen twig ends were generally higher in N concentration than naturally cast needles. However, the N percentage of needles from fallen twig ends was only half that of needles from clipped twigs. The lower concentration of N in needles of fallen twig ends is probably associated with a developing state of senescence. As needles begin senescence, they apparently lose the ability to retain the more mobile elements (such as N) in competition with more physiologically active regions (Kramer and Kozlowski 1960). Parts of vegetation that are caused to fall "prematurely" probably contain more N than "naturally falling" material (Gosz et al. 1972). Little difference was noted between the percentage N of twigs and bark of fallen twig ends and that of clipped twigs.

Mistletoe contained 1.1% N. The N concentration of nest duff was also high (1.54%). The mean N concentration of peeled twigs was 0.33%, a value less than that of twigs and bark of natural litterfall. Analysis of a half-peeled twig dropped by a squirrel interrupted while feeding showed the unpeeled half contained 0.38% N, the peeled half 0.31% N. Chewed bits of bark stripped from a twig contained 0.46% N. Thus, the outer and inner bark of small twigs appear to have a greater N concentration than the inner woody portion. We did not analyze inner bark separately, but Patton (1974) found an inner bark sample of ponderosa pine that contained 0.67% N.

Components of litterfall did not differ in C concentration between feed and control trees. Nor did season of the year have any influence on C content of

[4] *Samples of clipped twigs taken for chemical analysis were generally removed from the portion of the clipped twig most distant from the terminal bud. The N concentration of the twig portion of clipped twigs presented is thus somewhat conservative.*

litterfall. The variations observed in figure 6 were apparently the result of experimental error and random variation. Carbon content of all three litterfall components (needles, bark and twigs, cones) varied less than 4% during the entire year (fig. 6).

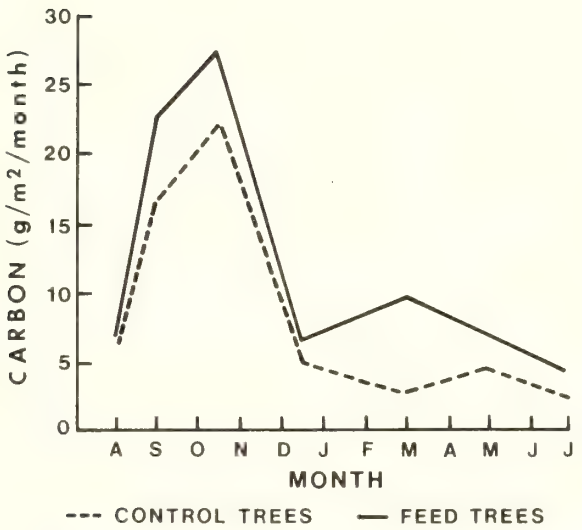


Figure 6.—Percentage carbon of needle, bark and twig, and cone components of litterfall for feed and control trees for seven collection periods.

No difference in C concentration was found between needle, bark and twig material of clipped twigs and that of fallen twig ends. Nor did percentage C differ between clipped twigs and components of "naturally" fallen litterfall. The chewed bits of bark apparently discarded by squirrels in the process of stripping twigs contained 51% C. The C content of peeled and unpeeled halves of the twig mentioned earlier were 49.2% and 50.3% respectively. The mean C concentration of mistletoe was 49.0% and that of nest duff only 43.3%.

Amount of Nitrogen and Carbon

Graphs (fig. 7) portraying amount of N transferred in litterfall from control and feed trees as a function of time are similar in appearance to those for dry weight (fig. 4). Late winter-early spring was the only period when total litterfall of control and feed trees differed significantly in weight of N, but the difference was large. During the February-April period, N in bark and twig, needle, and "other" litterfall components was greater under feed trees. Nitrogen transfer by needlefall also was greater from April to May and from June to July. The large difference between treatments in N for the "other" litterfall category was primarily the effect of clipped twigs under feed trees and led to the difference between treatments in N of total litterfall.

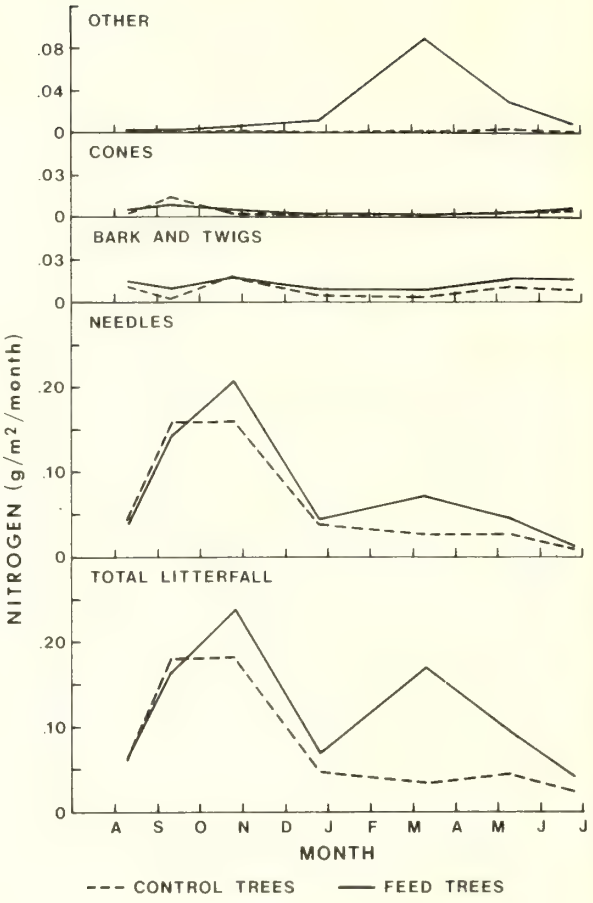


Figure 7.—Weight of nitrogen transferred per month from standing crop to the forest floor by litterfall of feed and control trees for seven collection periods.

In trees where squirrels actively fed, 15.3 kg/ha/yr of N were transferred to the forest floor (fig. 7), a significantly higher amount (70% higher) than from control trees. In the control treatment, only 9.0 kg/ha/yr of N were transferred via litterfall to the forest floor. Most of this N (81.6%) was transferred in the needlefall. Cone material, which accounted for only 3.2% of the total weight of litterfall, contributed almost 5.5% of the N in litterfall. Bark and twigs were low in N concentration but accounted for 11.9% of N in litterfall while "other" litterfall comprised 1.1% of the N.

The mean amount of N that fell in litterfall over the entire year was 12.2 kg/ha, considering both feed and control trees. This compares with 12.4 kg/ha/yr of N in an eastern deciduous forest (Wells et al. 1971). On a world basis, Rodin and Bazilevich (1967) reported the return of N to the forest floor in the coniferous zone varies between 10 and 50 kg/ha/yr and ranges even higher in plantations.

Because percentage C in litterfall varied little among components or between treatments, any difference between treatments in amount of C

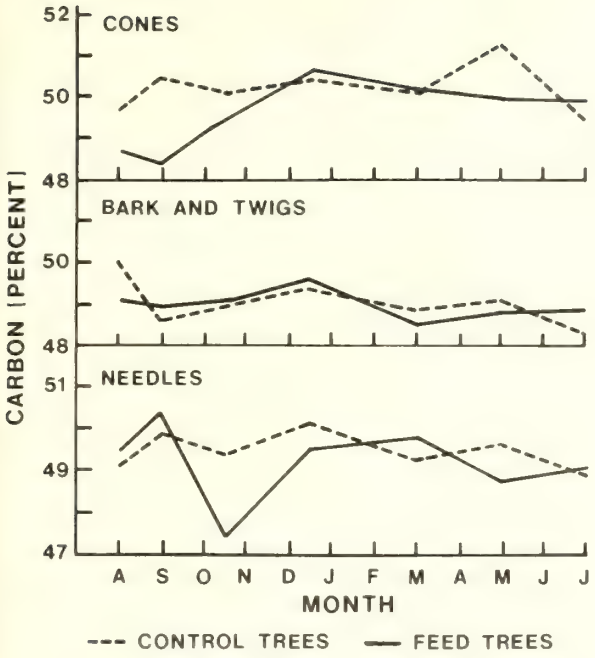


Figure 8.—Weight of carbon transferred per month from standing crop to the forest floor by total litterfall of feed and control trees for seven collection periods.

transferred via litterfall (fig. 8) is similar to differences noted in litterfall weight between treatments (fig. 4). When the total amount of C that fell via all litterfall components over the entire year is tallied, a significantly greater amount, almost 50% more, was found under feed than control trees. As was true of N, differences between treatments were observed only in late winter. From February to April, 3.6 times as much C was transferred through litterfall of feed trees as control trees. Amount of C in litterfall of feed trees exceeded that for control trees for all components except cone material.

Nest Characteristics

Although the nest of the Abert squirrel is roughly spherical, a small platform often extends beyond the bowl edge on one side. Nests are usually constructed on a large limb and against the bole of the tree, though on occasion nests were noted in the fork of large branches or out on a limb.

Twigs and branches made up 42% by weight of the structural components of the nest. Needles were the next largest component (26%) followed by loose (20%) and packed duff (12%). Packed duff, composed of an almost indistinguishable mass of pine needles, excrement, and other organic matter, had the highest N concentration (1.94%) of the four nest components. Loose duff had an N content of 1.54%, needles 1.26%, and twigs and bark only 0.6%. Loose and packed duff contained almost half the nest N.

Needles, twigs and bark of nests had a higher percentage N than did similar components of litterfall, probably because of excrement in the nest. Fecal pellets contained 2.3% N. Percentage C of needles, twigs and bark from nests was similar to that of litterfall. Percentage C of loose and packed duff (43.4% and 39.8%) was lower than any component of the litterfall.

Although N percentage of bits of nest duff found in litterfall was comparatively high, an average of only 0.37% g/m^2/yr of nest duff was found in litterfall of nest trees. If the rate of transfer of other nest components is comparable to that of duff material, it would be years before nutrients in the average nest were returned to the forest floor, except for soluble nutrients. These nutrients are probably returned on a continuing basis by throughfall and stemflow.

Conclusions

Abert squirrels had a significant effect on transfer of nutrients by litterfall from the standing crop to the forest floor for ponderosa pine trees inhabited and used for feeding by the squirrels. The squirrels' influence was expressed not only in clipped and peeled twigs discarded during the feeding process, but also in the fall of senescing needles and bits of bark and twigs. Undoubtedly, much of the loose needle, bark, and twig material found in litterfall is discarded from twigs in the process of feeding on inner bark, but it is possible squirrels also break off tree parts while climbing about looking for twigs. Trees with squirrel nests also had occasional minor amounts of nest parts in their litterfall. No difference was noted in nutrient transfer via litterfall between trees that served both as nest and feed trees and those that were used only as feed trees.

Although squirrels clipped twigs throughout the year, by far the greatest amount of clipping took place during late winter and early spring. This peak in feeding activity helps explain the differences found between treatments in litterfall from February to April and the trend in total litterfall differences between treatments in May to June.

Increase in total N and C in litterfall because of squirrel activities was associated primarily, though not solely, with the increase in total mass of litterfall, because percentage C varied very little among components. However, litterfall components did differ in percentage N. The N concentration of clipped twigs was nearly double that of comparable components of "natural" litterfall. It was through the clipped twig component of litterfall that Abert squirrels made their most significant contribution to the nutrient transfer process.

Nitrogen concentration in loose needles, the major component of litterfall, averaged 0.57% annually. Nitrogen concentration was highest during late winter and early spring and lowest in fall and early winter. Percentage N in bark and twigs varied little from a mean of 0.3%. Nitrogen concentration in cone

litterfall under control trees was higher than that of feed trees in May and tended to be higher throughout the year. This probably is a result of squirrel feeding activities because fewer seeds and more chewed cone and bract material were found under feed than control trees. Another possible explanation is the occurrence of differences in nutrient composition of cones between control and feed trees. Thus, perhaps trees selected by squirrels for feed trees differ nutritionally from control trees.

Abert squirrel nests serve to some extent as reservoirs or sinks for C and N. Needles, twigs, and bark of the nests had a higher percentage N than they had as components of litterfall. The duff material of nests had a greater N concentration than any of the "natural" components of litterfall. Nutrients are leached from nests by precipitation through the crown canopy and down the stem of the trees, probably at a more rapid rate than the return of nest parts with the litterfall. The latter seems very slow; only a minor fraction is apparently returned each year.

Results and conclusions in this paper are based on only one year's data. Hence, annual variations in these figures can be expected because of changes in squirrel populations, availability of other foods, and changes in feeding habits of the squirrel caused by other factors. If squirrel clipping activity were to increase to the levels Pearson (1950) reported for the 1940's, when he said it was "not unusual to find as many as 1,000 excised shoots underneath a single tree," the squirrel's impact on transfer of nutrients through litterfall might increase severalfold. Based on the present rate of transfer, even a threefold increase in clipping activity would mean an increase of nearly 20 kg/ha/yr of N transferred. This is about twice the amount of N transferred under the control trees in this study, an amount that is close to the average for the pine forest of central Arizona (Klemmedson, unpublished data). In view of the steady state conditions that seem to prevail in the study area and in similar pine forests of Arizona, squirrel clipping activity of the magnitude described by Pearson (1950) is not likely except in local and unusual circumstances and for short durations.

Literature Cited

Allison, L. E., W. B. Bollen, and C. D. Moodie. 1965. Total carbon. *In* Methods of soil analysis, Part 2, p. 1346-1366. Chemical and microbiological properties. C. A. Black (ed). Monogr. No. 9, Am. Soc. Agron., Inc., Madison, Wis.

Bray, J. R., and E. Gorham. 1964. Litter production in forests of the world. Advan. Ecol. Res. 2:101-157.

Bremner, J. M. 1965. Total nitrogen. *In* Methods of soil analysis. Part 2, p. 1149-1178. Chemical and microbiological properties. C. A. Black (ed). Monogr. No. 9, Am. Soc. Agron., Inc., Madison, Wis.

Davis, James R., Peter F. Ffolliott, and Warren P. Clary. 1968. A fire prescription for consuming ponderosa pine duff. Res. Note RM-115, 4 p. Rocky Mt. For. and Range Exp. Stn., For. Serv., U.S. Dep. Agric., Fort Collins, Colo.

Gosz, J. R., G. E. Likens, and F. H. Bormann. 1972. Nutrient content of litterfall on the Hubbard Brook Experimental Forest, New Hampshire. Ecology 53:769-784.

Keith, J. O. 1956. The Abert squirrel (*Sciurus aberti aberti*) and its relationship to the forests of Arizona. M. S. Thesis. Univ. of Ariz., Tucson. 106 p.

Kramer, P. J., and T. T. Kozlowski. 1960. Physiology of trees. McGraw-Hill Book Co., N.Y. 642 p.

Patton, David R. 1974. Estimating food consumption from twigs clipped by the Abert squirrel. Res. Note RM-272, 3 p. Rocky Mt. For. and Range Exp. Stn., For. Serv., U.S. Dep. Agric., Fort Collins, Colo.

Pearson, G. A. 1950. Management of ponderosa pine in the southwest. U.S. Dep. Agric., Agric. Monogr. 6. 218 p.

Rasmussen, D. E., D. E. Brown, and D. Jones. 1975. Use of ponderosa pine by tassel-eared squirrels and a key to determine evidence of their use from that of red squirrels and porcupines. Wildlife Dig., Ariz. Game and Fish Dep. Abstr. 10, 12 p.

Rodin, L. E., and N. I. Bazilevich. 1967. Production and mineral cycling in terrestrial vegetation. Oliver and Boyd, London. 238 p.

Stark, N. 1973. Nutrient cycling in a jeffery pine forest ecosystem. Montana For. and Conserv. Exp. Stn., Univ. of Mont., Missoula.

Stephenson, R. L. 1975. Reproductive biology and food habits of Abert squirrels in central Arizona. M. S. Thesis. Ariz. State Univ., Tempe. 66 p.

Wells, C., D. Whigham, and H. Leith. 1972. Investigations of mineral nutrient cycling in upland piedmont forest. J. Elisha Mitchell Sci. Soc. 88:66-78.

1978

RESEARCH NOTE RM-354

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating Fuel Weights of Two Common Shrubs in Colorado Lodgepole Pine Stands[1]

Martin E. Alexander[2]

Abstract

Regression equations were developed for estimating fuel loadings of kinnikinnick and whortleberry shrubs from average height and/or percent crown cover. R^2 for the equations were 0.82 and 0.61, respectively. Guidelines for field application are given.

Keywords: *Arctostaphylos uva-ursi*, *Vaccinium* spp., forest fuel, shrub biomass.

In the southern Rocky Mountains, kinnikinnick (*Arctostaphylos uva-ursi* [L.] Spreng.) and grouse whortleberry/myrtle whortleberry (*Vaccinium scoparium* Leiberg/*V. myrtillus* L.) often dominate the understory of lodgepole pine (*Pinus contorta* Dougl.) stands at low and high elevations, respectively. These shrubs, depending on density, influence the spread of surface fires by partially supporting fine fuels (primarily fallen needle litter and small twigs) in a more optimumly aerated fuel bed than would form otherwise (Fahnestock 1976, Lawson 1972, Muraro 1964). In addition, once the preheating requirements of these shrubs is overcome, they contribute to combustion. A description of fuel weight (shrub biomass) is necessary to document the influence of these two species on potential fire behavior.

Shrub fuel quantities can be described by either (1) collecting material in the field and weighing it, or (2) predicting, which requires known relationships between weight and vegetative descriptors. Sampling techniques that involve clipping, drying, and weighing are time-consuming and tedious. Brown and Marsden (1976) recently formulated a regression equation using percentage of ground covered for estimating kinnikinnick fuel weights in the northern Rocky Mountains. Brown (1976) has also developed a linear regression equation for determining the total aboveground biomass of grouse whortleberry, a species with numerous fine stems. Brown (1976) felt that a technique using percent cover and height (Bentley et al. 1970) would probably be most efficient.

[1]*From a thesis submitted to the Graduate Faculty of Colorado State University in partial fulfillment of the requirements for the degree of Master of Science. Supported in part by Cooperative Aid Agreement 16-534 between the Rocky Mountain Forest and Range Experiment Station and Colorado State University. The author is indebted to Judson E. Brown who acted as a field technician during the sampling phase of the study.*

[2]*Formerly Graduate Research Assistant, Fire Science and Technology Program, Department of Forest and Wood Sciences, Colorado State University, Fort Collins. Alexander is now a Fire Research Officer with the Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.*

This Note presents a regional adaptation of the Brown and Marsden (1976) methodology for use in estimating kinnikinnick and whortleberry fuel weights. The work reported here resulted from a broader study to investigate relationships between downed woody fuel and forest floor loadings/depths, and stand structure/site characteristics in natural, even-aged lodgepole pine stands of the Colorado East Front Range (Alexander 1978).

Methods

Fuel sampling in 15 lodgepole pine stands where the understory was dominated by one of the two shrubs (10 kinnikinnick, 5 whortleberry stands) provided for a variety of stand and site conditions. Percent cover, average height, and weight were measured on a minimum of ten 2-square-foot quadrats that were systematically located at fixed intervals. The quadrats were delineated by a 1- x 2-foot frame. The field sampling techniques used were those developed by Brown[3]. In each quadrat, percent cover defined as the vertical project of plant area was sight-gaged and assigned a percent coverage class code: 1 = 0-5%; 2 = 6-20%; 3 = 21-40%; 4 = 41-60%; 5 = 61-80%; 6 = 81-95%; 7 = 96-100%. Midpoint values were treated as continuous independent variable quantities in the data analysis. Height was measured to the nearest inch from the forest floor to an estimated average plant top (Brown and Marsden 1976). Living and dead stem (all <0.25 inch in diameter for both shrub species) and leaf material above the forest floor within a vertical projection of the quadrat frame was clipped, oven dried at 100°C for 24 hours, and weighed to 0.01 gram.

[3]*Brown, James K. 1974. Fuel and vegetation inventory procedures—White Cap Study. Unpublished report on file with the USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Res. Work Unit FS-INT-2104, Missoula, Mont. 11 p.*

Data Analysis and Results

The average height of kinnikinnick seldom exceeded two inches so shrub height was disregarded as an independent variable. A least squares regression using percent cover accounted for 73% of the total variation in the data. A second degree polynomial regression yielded a better fit with an R^2 of 0.82. The resulting equation and pertinent statistics are contained in table 1.

As a basis for selecting the most statistically significant equation for estimating whortleberry loading, a matrix of simple correlation coefficients (r) was constructed between the following independent variable sets: cover, cover squared, height, height squared, cover and height, cover and height squared, cover squared and height, cover × height, cover × height squared, and cover squared × height. Intercorrelation between independent variable sets was checked for significant relationships. This resulted in the following satisfactory sets with their respective r versus weight:

Independent Variable Set	r
cover	0.51
cover squared	.47
height	.71
height squared	.74
cover × height	.78
cover × height squared	.79
cover squared × height	.71

The best regression selected used the product of cover × height; it accounted for 61% of the total variation in the data (table 1).

Discussion

The equations presented in table 1 exhibited F ratios significant at the 99.5% level. The expected variation of weight within a coverage class caused a poorer fit. The occurrence of minor herbaceous vegetation also contributed to some of the variation.

Table 1.—Equations for estimating shrub loading (Y), tons/acre, from cover (X_1), %, and plant height (X_2), inches.

Shrub species	Equation	R^2	F	SE	$\bar{Y}$
Kinnikinnick	$Y = 0.00219\ X_1 + 0.00014\ X_1^2$	0.82	268.104	0.085	0.109
Whortleberry	$Y = -0.06077 + 0.00180\ X_1X_2$	0.61	106.802	0.253	0.508

Brown and Marsden (1976) developed a second degree polynomial equation for estimating kinnikinnick fuel weights in western Montana and northern Idaho with an R^2 of 0.91. In their study, however, the average plant height was always greater than 4 inches, and pinegrass (*Calamagrostis rubescens* Buck.) was present in 84% of the cases as a major component. These two points probably account for the difference in the coefficients of the two equations. Thus, the equation presented in table 1 with an R^2 of 0.82 is recommended for Colorado conditions.

Of the 25 shrub species for which Brown (1976) developed linear regressions for estimating total aboveground biomass, all exhibited R^2 values of 0.84 or better except for two species. Grouse whortleberry was one of these, having an R^2 of 0.62. Considering the degree of precision versus time allocated, the percent cover × average height technique presented here (R^2 of 0.61) versus a tally of basal stems seems justified.

Conclusions

The regression equations developed here provide a convenient, nondestructive, relatively precise method for estimating shrub fuel weights of kinnikinnick and whortleberry. These weights can be used not only in modeling potential fire behavior, but also for such other purposes as estimating standing herbage crop and biomass development following fire. The equations may be less accurate for stands not dominated (<75% coverage) by one of the two shrubs.

Sampling Suggestions

Dry weights of the two shrubs per unit area can be determined in conjunction with other resource inventories. Rectangular or circular quadrats (2.0 ft^2 area) should be systematically spaced within the stand and ocular estimates made of percent cover (to the nearest 5% or 10%). For whortleberry, it will be necessary to determine average shrub height within the quadrat. Loadings can be determined by calculating the mean percent cover and height in the case of whortleberry, and using the appropriate equation or the nomogram (fig. 1). In addition, the amount of dead material could also be determined in the field by ocular estimating the percentage of the total weight. In terms of stand sampling intensities, at least 30 quadrats per acre will be needed to hold sampling errors to 25% for kinnikinnick and 10 per acre for whortleberry.

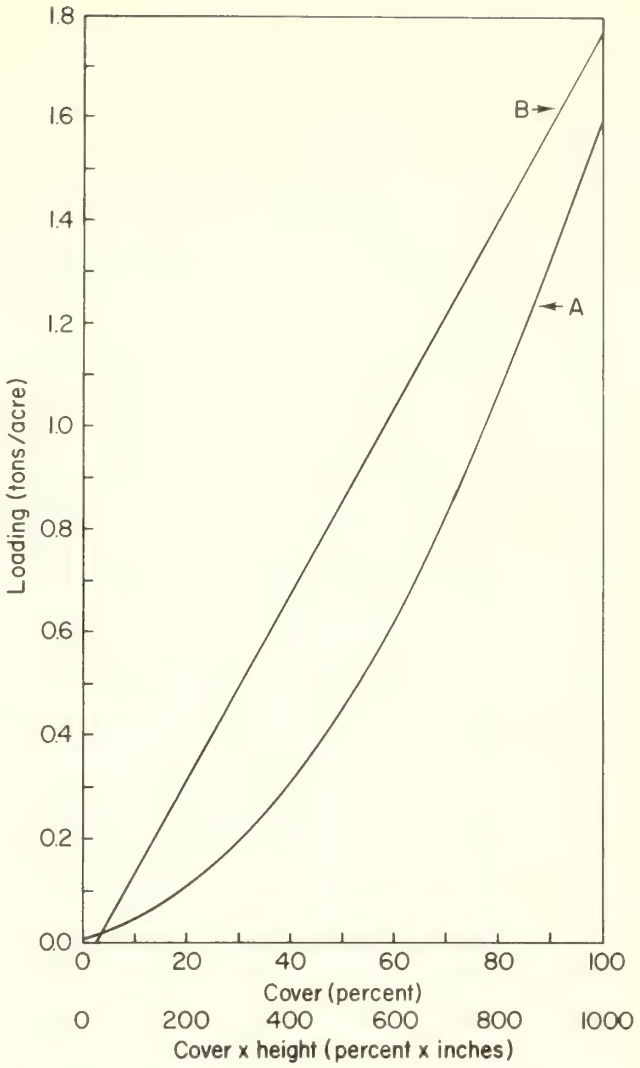


Figure 1.—Loading of kinnikinnick as a function of percent cover (A). Loading of whortleberry as a function of cover times height (B).

Literature Cited

Alexander, Martin E. 1978. Fuels description in lodgepole pine stands of the Colorado Front Range. M.S. Thesis, Colo. State Univ., Fort Collins.

Bentley, Jay R., Donald W. Seegrist, and David A. Blakeman. 1970. A technique for sampling low shrub vegetation, by crown volume classes. USDA For. Serv. Res. Note PSW-215, 11 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Brown, James K. 1976. Estimating shrub biomass from basal stem diameters. Can. J. For. Res. 6:153-158.

Brown, James K., and Michael A. Marsden. 1976. Estimating fuel weights of grasses, forbs, and small woody plants. USDA For. Serv. Res. Note INT-210, 11 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Fahnestock, George R. 1976. Fires, fuels, and flora as factors in wilderness management: The Pasayten Case. Proc. Tall Timbers Fire Ecol. Conf. (Oct. 16-17, 1974, Portland, Oreg.) 15:33-69.

Lawson, Bruce D. 1972. Fire spread in lodgepole pine stands. M.S. Thesis, Univ. Mont., Missoula. 119 p. [Also available as Can. For. Serv. Int. Rep. BC-36, Pac. For. Res. Cent., Victoria, B.C.]

Muraro, S. J. 1964. A method of measuring fire rate-of-spread in extracted samples of ground vegetation. Can. Dep. For. Publ. 1081, 11 p. Ottawa, Ont.

y 1978

RESEARCH NOTE RM-355

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Home Range and Movement of Five Mule Deer in a Semidesert Grass-shrub Community

Kenneth J. Rodgers, Peter F. Ffolliott, and David R. Patton[1]

Abstract

The home ranges of five desert mule deer (*Odocoileus hemionus crooki*) were determined on the Santa Rita Experimental Range between May 1975 and June 1976. Home range averaged 2.9 square miles, but varied for individual deer by season, sex, and age class. The area of activity within the home range was smallest during the spring and early summer and largest during the winter breeding season. The collared deer were found to be nonmigratory and restricted to the Experimental Range. Seasonal movements were within the home range. Minimum movement between consecutive days was approximately one-half mile in the spring and summer. Breeding season activity and disturbances by humans altered the normal movement pattern.

Keywords: Mule deer, deer behavior, deer home range.

Management Implications

Range scientists have advocated the control of shrubs to restore the potential productivity of perennial grasses (Parker and Martin 1952, Cable and Martin 1964, Reynolds and Martin 1968, Martin and Cable 1974). However, extensive shrub overstory removal would likely decrease the value of this habitat for deer. Limited vegetation conversion, though, may enhance range use by both livestock and wildlife. On suitable sites, small dispersed openings could increase forage yields while providing additional diversity in the habitat for deer. The availability of water on the Santa Rita Experimental Range during dry periods appeared to be adequate for efficient use of the habitat by deer.

[1]*Rodgers is Research Assistant and Ffolliott is Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Patton is Principal Wildlife Biologist, located at the Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Laboratory at Tempe, in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Introduction

Management of habitat for a given species of wildlife requires a knowledge of food, cover, and space requirements of the species. Research documenting the food habits of desert mule deer in the semidesert grass-shrub habitat on the Santa Rita Experimental Range has been published by Short (1977). This study was initiated to complement Short's work by (1) determining home range and movements of deer in a semidesert habitat, and (2) describing the influences of environmental factors on the seasonal patterns of use and activity.

Study Area

The study area was the 50,000-acre Santa Rita Experimental Range, 30 miles south of Tucson, Ariz. (fig. 1). Topography is a broad sloping bajada crossed by numerous dry shallow washes which drain northwest toward the Santa Cruz River. Elevations range from 2,800 to 4,500 feet. The Experimental Range is bordered on the east and south by the Santa

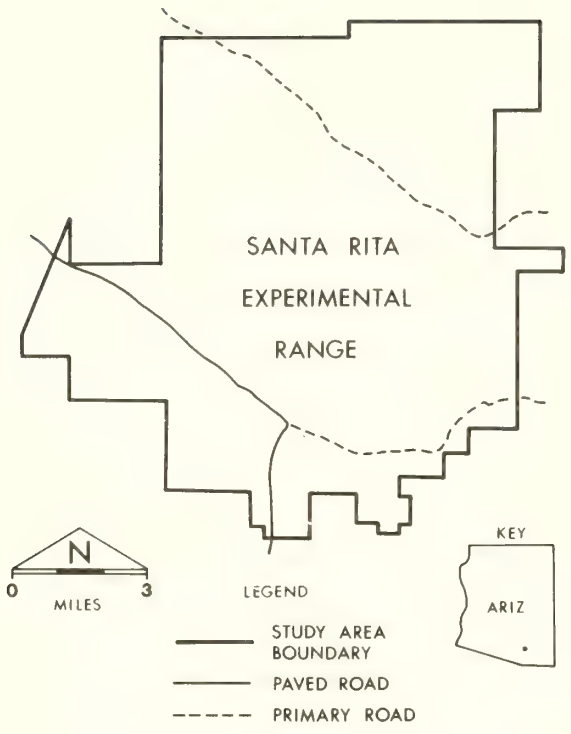


Figure 1.—Location of study area.

Rita Mountains, which rise abruptly to over 9,000 feet in the southern section. Irrigated agricultural land in the Santa Cruz Valley lies 2 to 3 miles west.

Annual rainfall ranges from 10 to 20 inches, with more than half occurring during the July through September rainy season. Winters are mild, and summers hot with humid periods during thunderstorms. An extensive pipeline system supplies permanent water to 20 experimental pastures. Stock ponds supply intermittent water for livestock and wildlife at other locations.

Vegetation is a sparse understory of perennial grasses overtopped by invasion stands of velvet mesquite (*Prosopis juliflora* var. *velutina*), cactus, and other shrubs. In general, vegetation increases in density with increasing elevation. Overstory vegetation between 3,200 and 3,600 feet is dominated by mesquite, burroweed (*Happlopapus tenuisectus*) and jumping cholla (*Opuntia fulgida, O. versicolor,* and *O. spinosior*). Engelmann pricklypear (*O. engelmannii*), catclaw acacia (*Acacia greggii*) and false mesquite calliandra (*Calliandra eriophylla*) are more prominent species at higher elevations (Martin and Reynolds 1973).

Areas below 4,000 feet typify desert mule deer habitat. Within this habitat, major food items are the foliage of leguminous trees and shrubs, fruit of cactus, notably barrel cactus (*Ferocactus wislizeni*), and seasonal forbs (Short 1977). Vegetative cover above this elevation grades into an oak-woodland type in the foothills and mountains.

The Experimental Range is classified as a Wildlife Area by the Arizona State Game and Fish Commission. With the exception of experimental hunts in 1954, 1964, and 1968 through 1972, the area has been closed to deer hunting since the 1930's[2].

Methods

Five deer were captured and fitted with radio collars to monitor daily and seasonal locations and activities. Collars consisted of a transmitter, antenna, and battery enclosed in Urelane (Furane Plastics, Inc.)[3] and attached to a 2-inch-wide leather strap. Collars were wrapped with colored vinyl electrical tape for field identification. An additional 3- x 5-inch fluorescent orange tag with black numerals was placed on the collar. The completed collar weighed from 1 to 3 pounds. Handheld three-element yagi and dipole directional antennas were used with a portable receiver to monitor signals.

A compass was used to determine the bearings of radio signals from hilltops, road intersections, and fence corners. At least two bearings were recorded for each deer location. On occasion, fixed-wing aircraft were used to locate deer whose signal was not heard on the ground. Intersecting signal directions were used to plot deer locations on a topographic map. The outermost points were then connected to delineate the area of activity.

Home ranges were determined by the minimum area method (Mohr 1974). For deer tracked throughout several seasons, home ranges were subdivided to represent areas of seasonal use. Plotted locations were examined to determine habitat use and movement patterns by season. For successive days of location, the linear distance between location points was measured as an approximation of minimum daily movement.

[2]*Personal communication with S. Clark Martin, Range Scientist, Rocky Mountain Forest and Range Experiment Station.*

[3]*Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment.*

Table 1.—Home range estimates for five radio-collared deer.

Deer Number	Age and Sex	Transmitter Life (2 days)	Number of Locations	Home Range (mi^2)	Time Period
1	Adult, female	78	40	2.8	June 12, 75-Aug. 28, 75
2	Adult, male	[1]378	27	2.4	May 26, 75-Oct 26, 75
				4.8	May 26, 75-Jun. 06, 76
3	Fawn, female	[1]131	25	1.5	Jan. 28, 76-Jun. 6, 76
4	Adult, male	[1]78	8	1.8	Mar. 20, 76-Jun. 6, 76
5	Yearling, female	220	27	2.8	Jun. 25, 75-Aug. 21, 75
				4.1	Jun. 25, 75-Mar. 16, 76
			127	X=2.9	

[1]*Transmitter was functioning at the termination of study.*

Results

Deer were tracked from May 28, 1975 to June 6, 1976. Home range sizes were estimated using 5 points of capture, 38 sightings, 69 ground locations, and 15 locations from the air. Home ranges for individual deer varied by season, sex, and age class. Areas ranged from 1.5 square miles for an adult doe and two fawns, during January to June, to 4.8 miles for a mature buck over a 12-month period (table 1).

The home ranges were generally elliptical with variable orientation. Each home range included two or more permanent watering areas along the periphery. In contrast, Hanson and McCulloch (1955) found water sites in Arizona brushlands were often in the center of a home range when suitable habitat was available in the surrounding area. Observed home ranges were intermediate in size relative to those reported for nonmigratory mule deer in other locations in the Southwest (Dasmann and Taber 1956, Hanson and McCulloch 1955, Swank 1958, Clark 1953).

Our data suggest that deer at Santa Rita may occupy different sized areas and sections within their home range in different seasons. The area of activity was smallest during the spring and early summer. Following summer rains, the home range began to enlarge, and continued to increase or shift during the fall and winter, reaching maximum during the breeding season. With exception of the rut, this seasonal pattern was similar to findings in the Tucson Mountains (Clark 1953).

Although size of areas occupied during seasons varied, the area of summer activity seemed to represent the core of the home range (fig. 2). Bucks occupied a larger home range on a yearly basis than does. Other home range studies indicate this same pattern (Clark 1953, Dasmann and Taber 1956, Swank 1958).

Movements

Movements of collared mule deer on the Experimental Range were not extensive. Deer were essentially nonmigratory and occupied a restricted home area all year. Other studies in the Southwest have reported similar results

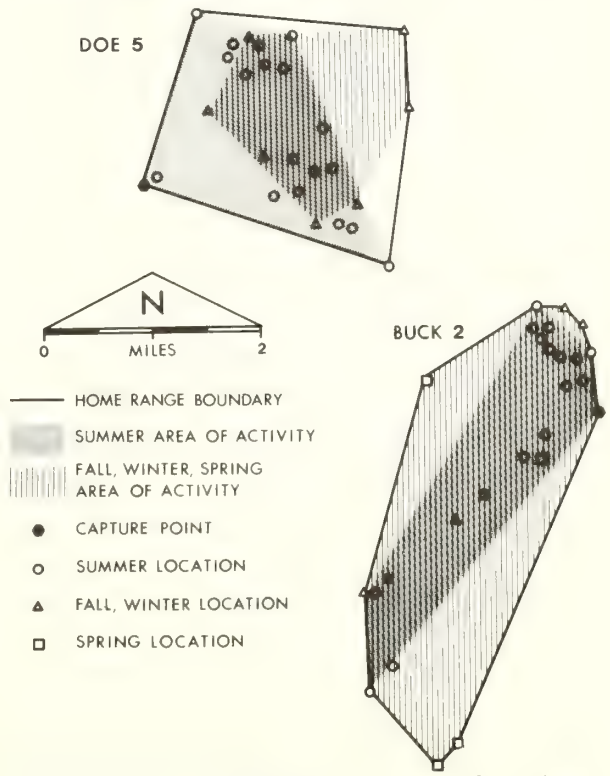


Figure 2.—Yearly and seasonal home ranges of two desert mule deer.

Table 2.—Average minimum deer movement between consecutive days and within single days.

Deer	Period	Number Consecutive Days	Aver. Movement Between Consecutive days *(mi.)*	Range *(mi.)*	Number of Days	Aver. Movement Within a Single Day *(mi.)*	Range *(mi.)*
1	Jun.-Aug.	12	.45	.1-1.0	10	.25	.1-.63
2	Jun.-Jul.	5	.46	.2-.6	1	(1)	
3	Mar.-Apr.	3	.56	.35-1.1	2	.28	.15-.4
5	Jun.-Jul.	4	.45	.2-.65	2	.62	.25-1.0
All		24	.49	.1-1.1	15	.29	1-1.0

[1]*Insufficient sample size.*

(Clark 1953, Truett 1971, Lang 1957). Seasonal movements were primarily shifts within the home range. Movements outside of the home range to adjacent areas of greater forage or water availability were not observed.

Throughout the year, deer fed and watered in mornings and evenings. Deer usually bedded during the day, but could be seen feeding at all hours during the day in the winter. Areas of good cover, especially the dry washes, were used for bedding grounds in all seasons. Most watering in winter occurred in the mornings. Late evenings and nights were summer watering times.

Estimates of minimum daily movement between consecutive days and minimum movement within particular days were obtained from four collared deer (table 2). Minimum movement between consecutive days averaged about one-half mile during the summer of 1975 and spring of 1976. Daily deer movements from less than 1 mile up to 5 miles in the Tucson Mountains, depend on climatic conditions (Clark 1953).

Data obtained on daytime travels indicated half of the movement between consecutive days in the summer occurred during the daylight period. Our data show that the daily cruising radius for deer on the Experimental Range was less than the 1 mile average radius found in the Arizona chaparral (Hanson and McCulloch 1955).

During the rutting season, mule deer occasionally left their home range. Bucks in December and January were active and moving throughout the day. The movements of buck No. 1 reflected a tendency to venture beyond his home range. Despite an aerial search in January, this buck could not be found in or near the area he frequented during the summer and fall. He was not found in his home range until April—more than 1 month after the rut. Other studies indicate that bucks may travel a mile or more beyond their home range (Dasmann and Taber 1956). Dixon (1934) documented California mule deer movements of 10 miles during one night.

Factors Influencing Movements

Cover and Food

Most of the Santa Rita Experimental Range has sufficient shrub densities to provide concealment for deer. Pastures cleared of mesquite were an exception. The lack of cover on these areas restricted deer use during daylight periods. Numerous dry washes on portions of the Experimental Range with little cover were important. These drainages and their associated vegetation provided resting, feeding, escape, and travel cover for the five deer throughout the year. In addition, the relief in these areas afforded protection from weather. Although the washes comprised a small segment (approximately 3%) of the area, 33% (163) of all sightings were in wash areas.

Truett (1971) indicated deer used areas that had palatable forage, as a result of the effects of topography. However, selection of feeding areas based on the influences of relief was limited on the Experimental Range. The gentle topography at Santa Rita did not provide marked contrasts in slope and aspect as in studies by Truett (1971) and Anthony (1972).

Water Availability

Signs at water developments on the Experimental Range suggested that deer increased their water use in the dry periods of May-June and September-October. Observations, however,

did not indicate that deer concentrated near these water sources. Collared deer remained within 1 to 1-1/2 miles of permanent water during the dry periods; subsequent monitoring revealed that this distance was also the extent of their home range during wetter periods. Movements to areas of permanent water were evident, but did not require extensive adjustments in activities. On one occasion, the drying of a waterhole resulted in a doe shifting one-half mile to a new activity area with a more reliable water source.

Water distribution on the Experimental Range is better than the surrounding semi-desert habitat. The maximum distance from a permanent water source was 2.4 miles during the early summer, when many surface stock tanks were dry. After these tanks had been replenished by summer rains, the maximum distance was 1.9 miles (fig. 3). These seasonal changes in water availability did not have a noticeable impact on deer movement and did not limit their use of the habitat.

Weather

Deer were more active during the cooler parts of the day in the summer, and sought shelter in washes from the heat and sun during midday.

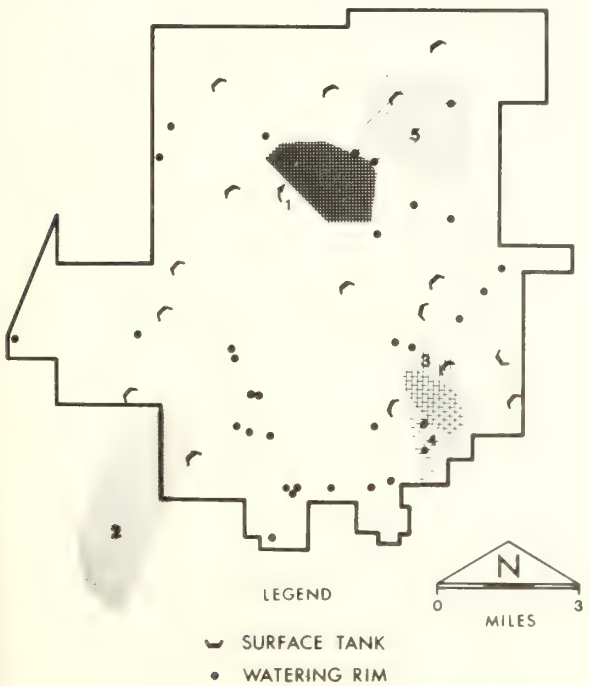


Figure 3.—"Minimum area" home ranges of five desert mule deer and water distribution patterns on the Santa Rita Experimental Range.

Deer were active throughout the day in the winter. The weather at Santa Rita apparently did not cause seasonal migrations, although Truett (1971) mentioned that topography often afforded this means of thermoregulation. The gentle and uniform nature of the topography on the Experimental Range limited the variety of exposures to accomplish these adjustments.

Human Disturbances

Following capture, one deer (No. 3) readily associated with others, and within several days, the deer groups appeared to return to their normal movement and activity patterns. Radio collars were assumed not to have a significant effect on the behavior or interactions of instrumented animals.

Humans caused deer movements. In many instances, radio locations were followed by attempts to sight and observe deer activities. Their reactions to these disturbances varied from a short run with little change in location, to movements of almost 2 miles during the period of 1 day. In some cases, movements resulted in deer returning to the same area a short time later, or in the case of extended travel, to a new area of activity. For example, doe No. 1 remained in an area 1,200 feet in diameter for 2 weeks despite five sightings that interrupted her activities during this time. In another instance, buck No. 2 shifted his area of activity 3-1/2 miles after several sightings. Provocation at this new location caused a return movement to the original area. This deer moved irregularly between these two areas.

The fall deer hunting season had a noticeable effect on deer movements and activities. On the Experimental Range, which was closed to legal deer hunting, other research personnel reported an influx of deer to areas within the range boundaries. The movements of buck No. 2 reflected this apparent deer response to hunting. He was located in an area 2 miles outside the Experimental Range boundary 1 week before the beginning of the hunt. Two days before the season and during the first 3 days of the 9-day hunt, he could not be located within the portions of his home range outside the Experimental Range. Hunters who were questioned did not report sighting this buck. One day after the season's end, he was located by aircraft on the Experimental Range within his home area. He remained in this vicinity for several weeks before leaving the Range again.

Livestock Grazing

Seasonally, there was a potential for competition between livestock and deer for some forage items, such as mesquite beans, false mesquite (a highly preferred browse plant), and ephemeral forbs. At present, cattle are stocked to obtain approximately 40% use of the perennial grass resources (Martin and Cable 1974).

Presence of cattle did not appear to affect deer preference for a portion of their home range. The only disturbances which temporarily displaced the deer from their activity areas resulted from livestock movement at roundup time.

Literature Cited

Anthony, Robert G. 1972. Ecological relationships between mule deer in southeastern Arizona. Ph.D. diss., Univ. Ariz., Tucson, 123 p.

Cable, Dwight R. and S. Clark Martin. 1964. Forage production and stocking rates on southern Arizona ranges can be improved. U.S. For. Serv. Rocky Mt. For. and Range Exp. Stn. Res. Note RM-30, 11 p. Fort Collins, Colo.

Clark, E. Dan. 1953. A study of the behavior and movement of the Tucson Mountain mule deer. M.S. thesis, Univ. Ariz., Tucson, 111 p.

Dasmann, R. F. and R. D. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. J. Mammal. 37(2):143-164.

Dixon, Joseph S. 1934. A study of the life history and food habits of mule deer in California. Calif. Fish and Game 20(3):181-282 and 20(4):315-354.

Hanson, W. R. and C. McCulloch. 1955. Factors influencing mule deer in Arizona brushlands. Trans. North Am. Wildl. Conf. 20:568-588.

Lang, E. M. 1957. Deer of New Mexico. N. Mex. Dep. Game and Fish Bull. No. 4, 41 p.

Martin, S. Clark and Dwight R. Cable. 1974. Managing semidesert grass-shrub ranges. USDA For. Serv. Tech. Bull. No. 1480, 45 p.

Martin, S. Clark and Hudson G. Reynolds. 1973. The Santa Rita Experimental Range: Your facility for research on semidesert ecosystems. Ariz. Acad. Sci. 8(2)56-57.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37(1):223-249.

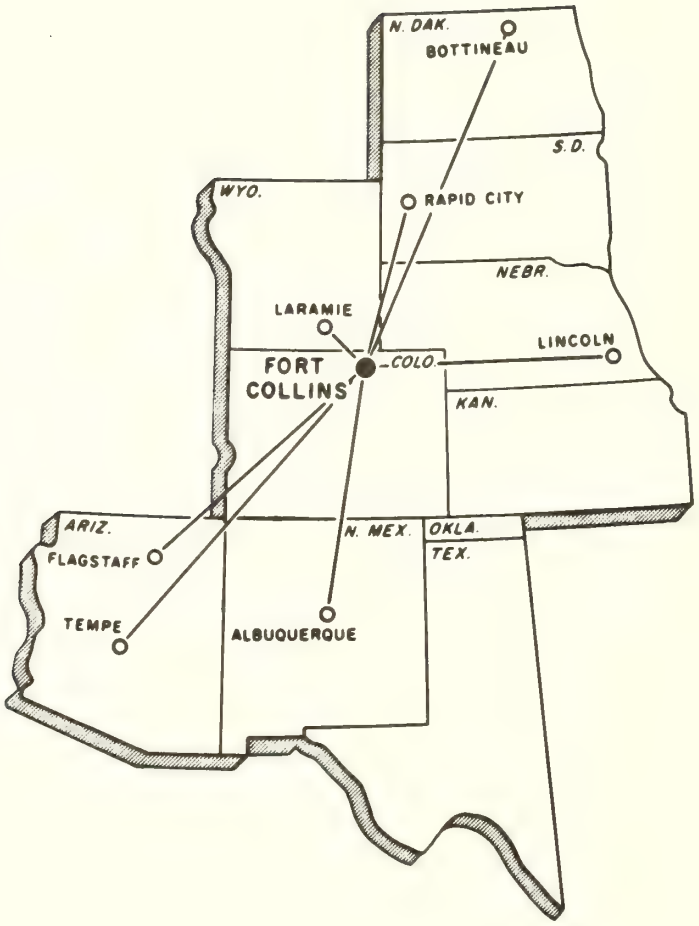
Parker, Kenneth W. and S. Clark Martin. 1952. The mesquite problem on Southern Arizona ranges. U.S. Dep. Agric. Circ. No. 908, 70 p.

Reynolds, Hudson G. and S. Clark Martin. 1968. Managing grass-shrub cattle ranges in the Southwest. U.S. Dep. Agric., Agric. Handb. No. 162, 44 p.

Short, Henry L. 1977. Food habits of mule deer in a semidesert grass-shrub habitat. J. Range Manage. 30:206-209.

Swank, Wendell G. 1958. The mule deer in Arizona chaparral. Ariz. Game and Fish Dep., Wildl. Bull. No. 3, 109 p.

Truett, J. C. 1971. Ecology of the desert mule deer, *Odocoileus hemionus* (Mearns), in southern Arizona. Ph.D. diss. Univ., Ariz. 64 p.


N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT
COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE

1978

RESEARCH NOTE RM-356

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Duration of Deer Forage Benefits After Clearcut Logging of Subalpine Forest in Colorado

Wayne L. Regelin and Olof C. Wallmo[1]

Abstract

In subalpine forests of central Colorado, measurement of use by mule deer (*Odocoileus hemionus*) 2, 10, and 15 years after clearcut logging, and forage production 15 and 20 years after logging, indicate an initial negative, but brief, habitat influence followed by benefits that peak before 15 years but persist well beyond 20 years.

Keywords: Deer forage, logging.

During the secondary succession following logging, deer forage supplies increase for a period of years, then decrease as the forest canopy closes. If the time scale for this process were defined for each forest type, cutting rotations could be designated to better serve multiple-use management goals. This sequence was studied with respect to forage supplies for mule deer in subalpine forests on the Fraser Experimental Forest in central Colorado.

In 1954-56 a small watershed, Fool Creek, was logged in alternating clearcut and uncut strips as an experiment in multiple-use forest management (Alexander 1957, Goodell 1958). The cut strips were 1, 2, 3, and 6 chains wide, with all trees larger than 4 inches d.b.h. felled. Uncut strips were the same width as adjacent cut strips (fig. 1).

Two years after logging, deer used cut strips less than uncut strips (Porter 1959) However, 12 years after logging, use of the cut strips was triple that of uncut strips, and use on the Fool Creek watershed was double that on an adjacent control watershed (Wallmo 1969). Food habits of deer were determined 15 years after logging in the cut and uncut strips. The tame deer used in this study preferred to graze in cut strips, spending 72% of their time and obtaining 70% of their forage in these areas (Wallmo et al. 1972). At that time, the end-of-season standing crop of understory herbage on the cut strips exceeded the crop on uncut strips by 463 ± 214 pounds per acre (Wallmo et al. 1972). There was a greater number of species in the cut strips, but no apparent differences in the nutritional quality of forage plants (Regelin et al. 1974). Herbage yields were measured again 20 years after logging. This paper compares 15-year and 20-year post-logging results.

Methods

The herbage crop was sampled in August 1975 by the same methods used in August 1970 (Wallmo et al. 1972). On 10 pairs of adjacent cut or uncut strips, fifty 1- x 2-foot quadrants were clipped on each strip. The 13 major forage species were clipped and sacked individually, and all other species, including those occasionally grazed, were sacked together. All live plant material, except conifer species, in or

[1]*Regelin is now Range Scientist, U.S.D.I. Fish and Wildlife Service, Denver Wildlife Research Center, Kenai, Alaska. Wallmo is Principal Wildlife Biologist, Pacific Northwest Forest and Range Experiment Station, located at the Station's Research Work Unit at Juneau, Alaska.*

Figure 1. Photo of Fool Creek.

overhanging the quadrant up to 5 feet was clipped. Samples were dried at 100° C for 24 hours and weighed to the nearest 0.1 g. Differences in herbage and forage yields between cut and uncut strips were evaluated using a two-way analysis of variance for 1970 and 1975 data separately. Differences within cut and uncut strips between 1970 and 1975 were also evaluated by a two-way analysis of variance. In all cases, the level of difference considered significant is $P < 0.05$.

Results

Both in 1970 and 1975, 15 and 20 years after logging, there was a significantly greater amount of forage and nonforage species on cut strips than on uncut strips (table 1). From 1970 to 1975, the estimated herbage yield decreased on cut strips and increased on uncut strips, and the crop of 13 major forage species increased in both treatments. However, these changes were not significantly different. Yields of *Vaccinium* spp. (*V. scoparium* and *V. myrtillus*), the major contributor to herbage biomass and to deer diets, did not change significantly from 1970 to 1975 (table 2). Among the major forage species, the only statistically significant change was a decrease in *Rosa acicularis* on cut strips. The only other significant change was a decrease in nonforage species on cut strips.

In 1970, the estimated herbage crop on cut strips was 118% greater than on uncut strips, and, in 1975, only 75% greater. The crop of forage species on cut strips was roughly 47% and 36% greater on cut than on uncut strips in 1970 and 1975, respectively. In 1970, there was approximately 23% and, in 1975, 8% more *Vaccinium* spp. on cut strips than on uncut strips. The magnitudes of these estimated differences is not great, but they suggest that differences in biomass of understory vegetation between cut and uncut strips is narrowing.

Table 1. Standing crop biomass (± 95% confidence interval) in cut and uncut strips on Fool Creek Watershed, Fraser Experimental Forest, Colorado during 1970 and 1975

	Pounds per acre			
	Cut Strips		Uncut Strips	
Vegetation Category	1970	1975	1970	1975
Forage species	509 ± 39	554 ± 46	346 ± 31	408 ± 40
Nonforage species	344 ± 54	205 ± 35	45 ± 18	25 ± 8
Total	853 ± 61	759 ± 56	391 ± 35	433 ± 41

Discussion

Twenty years after logging spruce-fir and lodgepole pine forests, the production of understory herbage and deer forage was still greater on cut areas than on adjacent uncut areas. The estimated change from 15 to 20 years after logging was not great nor statistically

Table 2. Standing crop biomass (± 95% confidence interval) of the 13 major forage species[1] in cut and uncut strips on Fool Creek Watershed, Fraser Experimental Forest, Colorado in 1970 and 1975.

	Pounds per acre			
	Cut Strips		Uncut Strips	
Species	1970	1975	1970	1975
Vaccinium spp.[2]	397.0 ± 38.6	410.2 ± 43.7	321.8 ± 30.7	378.2 ± 39.4
Arnica cordifolia	40.9 ± 6.5	47.0 ± 7.2	14.3 ± 4.2	14.7 ± 4.0
Epilobium angustifolium	47.1 ± 10.1	47.9 ± 9.9	0.1 ± 0.1	0.1 ± 0.1
Taraxacum officinale	8.6 ± 2.3	7.8 ± 3.1	0.2 ± 0.2	0.1 ± 0.2
Senecio crassulus	8.8 ± 3.9	7.5 ± 2.8	0.8 ± 0.8	1.3 ± 0.8
Rosa acicularis	6.4 ± 2.6	1.8 ± 0.7	0.5 ± 0.4	0.2 ± 0.3
Saxifraga arguta	6.4 ± 4.3	5.5 ± 3.2	2.1 ± 2.1	0.8 ± 1.0
Sheperdia canadensis	3.4 ± 4.7	2.9 ± 2.5	2.5 ± 3.4	4.8 ± 6.7
Lonicera involucrata	2.8 ± 3.8	12.1 ± 16.2	0.3 ± 0.5	0.8 ± 0.8
Fragaria ovalis	2.6 ± 1.7	7.6 ± 4.2	0.2 ± 0.2	0.8 ± 1.1
Pyrola spp.[3]	1.6 ± 1.3	1.0 ± 2.1	3.9 ± 1.6	5.2 ± 2.1
Streptopus amplexifolius	0.8 ± 0.5	0.4 ± 0.4	0.1 ± 0.3	0.3 ± 0.4
Salix spp.	0.5 ± 1.0	0.7 ± 0.9	0	0.4 ± 0.5

[1] *Nomenclature generally conforms to Harrington (1954). Identification by Charles Feddema, Curator, Forest Service Herbarium, Fort collins, Colo. Voucher specimens in that Herbarium.*
[2] *Include V. scoparium and V. myrtillus.*
[3] *Include P. minor and P. asarifolia.*

significant, but the direction of change suggests that the difference in understory biomass between cut and uncut areas was decreasing. *Vaccinium* spp. dominate the understory vegetation on most sites in the mature forest. The increased abundance of *Vaccinium* in cut areas in the 20th year after logging and the decreased difference in the amount of *Vaccinium* in cut and uncut areas may reflect the influence of developing forest canopy.

Literature Cited

Alexander, Robert R. 1957. Damage to advanced reproduction in clearcutting spruce-fir, U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn. Res. Note 27. 3 p.

Goodell, B. C. 1958. A preliminary report on the first year's effects of timber harvesting on water yields from a Colorado watershed. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 36. 12 p.

Harrington, H. D. 1964. Manual of the plants of Colorado. 2nd ed. Sage Books, Denver. 666 p.

Porter, Kenneth A. 1959. Effects of subalpine timber cutting on wildlife in Colorado. M.S. Thesis. Colo. State Univ. 92 p.

Regelin, Wayne., Olof C. Wallmo, Julius G. Nagy, and Donald R. Dietz. 1974. Effects of logging on forage values for deer in Colorado. J. For. 72(5):4-7.

Wallmo, Olof C. 1969. Response of deer to alternate-strip clearcutting of lodgepole pine and spruce-fir timber in Colorado. USDA For. Serv. Res. Note RM-141, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Wallmo, Olof C., Wayne L. Regelin, and Donald W. Reichert 1972. Forage use by mule deer relative to logging in Colorado. J. Wildl. Manage. 36(4):1025-1033.

978

RESEARCH NOTE RM-357

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of Watering Treatments on Germination, Survival, and Growth of Rocky Mountain Douglas-fir: A Greenhouse Study

Daniel L. Noble, Carleton B. Edminster, and Wayne D. Shepperd[1]

CLEMSON UNIVERSITY LIBRARY
DEC 15 1978
TECH. & AGR. DIV.

Abstract

Amount and distribution of water from 0.0 to 2.0 inches per month affected germination, survival, and growth of Douglas-fir seedlings. Germination increased when increasing amounts of water were distributed evenly during the month, but was not affected when water was applied once a month. Survival was acceptable when seedlings received 1 inch or more of water distributed throughout the month. Seedling growth was increased slightly with 2.0 inches of water per month.

Keywords: *Pseudotsuga menziesii* var. *glauca*, plant-water relations, plant physiology, seed germination.

Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) is considered one of the climax species in montane forests of the central Rockies (Oosting 1956). In Colorado, on the east side of the Continental Divide, the species predominates on northerly aspects between elevations of approximately 6,000 to 9,500 feet (1,830-2,900 m) with lodgepole pine (*Pinus contorta* subsp. *latifolia* (Engelm. ex Wats.) Critchf.) as a major associate and occasional aspen (*Populus tremuloides* Michx.), Engelmann spruce (*Picea engelmannii* Parry), blue spruce (*Picea pungens* Engelm.), and ponderosa pine (*Pinus ponderosa* var. *scopularum* Engelm.). These Douglas-fir forests have major watershed, esthetic, recreation, and wildlife values.

Regeneration success following disturbances is critical to the silviculture and management of these forests. Little information is available concerning reproduction of Douglas-fir in Colorado, but information from other areas indicates that regeneration could be a problem. Previous studies in the northern and central Rockies indicate that moisture can limit Douglas-fir on the more severe sites, especially in the southern range of the species or east of the Continental Divide (Hayes 1965, Ryker 1975). Studies in the Southwest

[1]*Plant Ecologist and Associate Mensurationist, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Shepperd is Forest Silviculturist, Rio Grande National Forest, Monte Vista, Colo.*

further indicate that first-season seedlings are shallow rooted, and few survive to the second year (Jones 1967, 1971). Krauch (1956) also found that Douglas-fir seedlings germinating on exposed sites in Arizona and New Mexico did not survive without weekly precipitation.

The studies reported here were made under controlled greenhouse conditions to supplement field observations. Germination, initial survival, and early growth of seedlings were compared under watering treatments selected to represent the precipitation patterns most common on typical Douglas-fir sites in central Colorado[2].

Methods and Materials

Seed Source

Rocky Mountain Douglas-fir seed was collected locally from the Pike National Forest in 1973 and stored at 4°C. Average laboratory germination was 63%.

Soil and Seeding

Forest soil from 7,800 feet (2,377 m) elevation on the Manitou Experimental Forest was used. It is a coarse sandy-loam developed from Pikes Peak granite and covers much of the Experimental Forest (Marcus 1973, Retzer[3]). Moisture holding capacities at ⅓ and 15 bars determined in the laboratory, were approximately 24% and 13%, respectively. The soil was screened through 4-mesh hardware cloth, thoroughly mixed and placed in pots—7 inches (18 cm) deep and 6 inches (15 cm) in diameter—which were soaked to saturation twice a day for 3 days. Twenty seeds were then sown on the surface of the soil in each pot. All pots were again soaked to insure soil moisture was near saturation before watering treatments were begun. A total of 150 pots were prepared.

[2]*USDA Forest Service weather records for a 35-year period (1941-75) from the Manitou Experimental Forest, Colorado (records on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.) indicate that average precipitation for the months May and June (critical months for germination and initial seedling establishment) is 1.90 and 1.65 inches (4.8 and 4.2 cm) respectively. Precipitation for these months, generally ranging from 0.14 to 5.05 inches per month (0.4 to 12.9 cm), is most likely to fall in either several small storms of 0.25 inch (0.6 cm) or less, or in one or two larger storms.*

[3]*Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. 18 p. [Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.]*

Experimental Design and Treatment

The study consisted of two experiments. In experiment A, pots received 0.0, 0.5, 1.0, 1.5, or 2.0 inches (0.0, 1.3, 2.5, 3.8, or 5.1 cm) of water monthly, uniformly distributed throughout the month in applications of 0.25 inch (0.6 cm). In experiment B, pots received the assigned level of water once a month. Both experiments were arranged in a randomized block design with 15 replications.

Greenhouse Environment

Environment in the greenhouse at Fort Collins, Colo. was maintained as closely as possible to average field conditions during the growing season on north aspects on the Manitou Experimental Forest. Air temperatures were 70°F (21°C) day and 40°F (4°C) night. The photoperiod was 16 hours of natural and artificial light; temperature changes coincided with photoperiod. Relative humidity was varied from 20% to 30% (day) to 70% to 80% (night). The high light intensity—up to 12,000 footcandles (fc, 129,000 lx)—associated with openings in the forest cover on the Manitou Experimental Forest could not be reached in the greenhouse. The normally lower light intensity at 5,000 feet (1,524 m) elevation was further reduced by the greenhouse glass, so that light intensity inside the greenhouse varied from 3,000 fc on cloudy days to about 5,000 fc on clear days.

Measurements and Analyses

Number of germinating seeds, number of surviving seedlings, and cause of mortality were recorded twice a week. At the end of 20 weeks, the soil was carefully washed from the roots of all live seedlings, and the top height and root length was measured to the nearest millimeter. The tissue then was ovendried for 24 hours at 100°C and weighed to the closest 0.1 mg.

Germination and survival were expressed as a percent of the number of seeds sown per pot; top height, root length, and total seedling dry weight were expressed as means of surviving seedlings per pot. Differences due to treatments were tested for significance by analyses of variance with arcsine transformation for percentage data. Tukey's method of simultaneous confidence intervals was used to determine which treatment differences were significant (Graybill 1976).

Results

Germination

In experiment A (water uniformly distributed during the month), total germination increased from 25% to 63% as the amount of water increased from none to 2.0 inches per month (fig. 1). Germination was not significantly increased until 1.0 inch or more of water was applied; the 2.0 inches per month had a significant increase over the 1.0 and 1.5 inches per month ($\alpha = 0.05 \leq \alpha < 0.10$).

In experiment B (water applied once a month), germination was not affected by increasing amounts of water. Total germination at the no water level was 23% and ranged from 18% to 24% at other watering levels (fig. 1).

Length of Germination Period

The length of time over which seedlings emerged was affected very little by either the distribution or amount of water received. In both experiments, germination began in about 14 days and was generally completed 28 days after sowing. In experiment A, germination occurred up to 42 days after sowing, with 1.0 inch or more of water per month. In experiment B, some delayed germination occurred following the second and third applications of water (fig. 2).

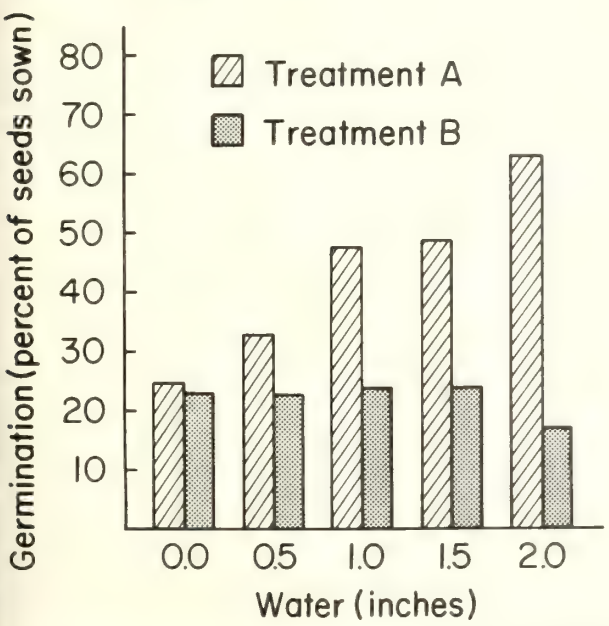


Figure 1.—Total germination in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Seedling Survival

Number of seedlings surviving after 20 weeks was related to both amount and distribution of water. When water was evenly distributed during the month, 1.0 inch monthly was required to sustain any significant survival—34% (fig. 3). Significantly more seedlings survived at 2.0 inches of water (55%) than at 1.0- and 1.5-inch levels ($\alpha = 0.05$). In contrast, few seedlings survived when water was applied only once a month. Survival percentages at the 1.0 inch or more level were not significantly different, ranging from 9% to 14% (fig. 3).

Causes of Mortality

In experiment A, drought was the principal cause of mortality at all levels of water, except 2.0 inches (table 1). Damping-off was an important cause of mortality at 1.5 inches or more. At these higher water levels, losses also resulted from failure to establish—the radicle emerged from the seedcoat and did not develop further, either because the seeds could not absorb sufficient water for the radicle to become rooted or seeds did not have enough germination vigor to complete establishment.

In experiment B, drought was the major cause of mortality at all treatment levels (table 1). Seedling losses from damping-off were important at 1.0 inch or more. Mortality from failure to establish was important but variable, and not necessarily related to amount of water received.

Seedling Growth

Plant growth for the two water distributions could not be compared statistically; however, except for higher seedling biomass at 2.0 inches per month in experiment A, it would appear that growth was about the same in both treatments. Seedling growth data for 0.5 inch per month were not included in the analyses in either experiment A or B because of poor survival.

With even distribution of water, seedling growth—total plant dry weight, top height, root elongation, and root/shoot ratio—appeared to increase with an increase in the amount of water applied; however, growth was not significantly affected except at 2.0 inches per month, where the seedlings were significantly heavier than either the 1.0 or 1.5 inches per month ($\alpha = 0.05$, table 2).

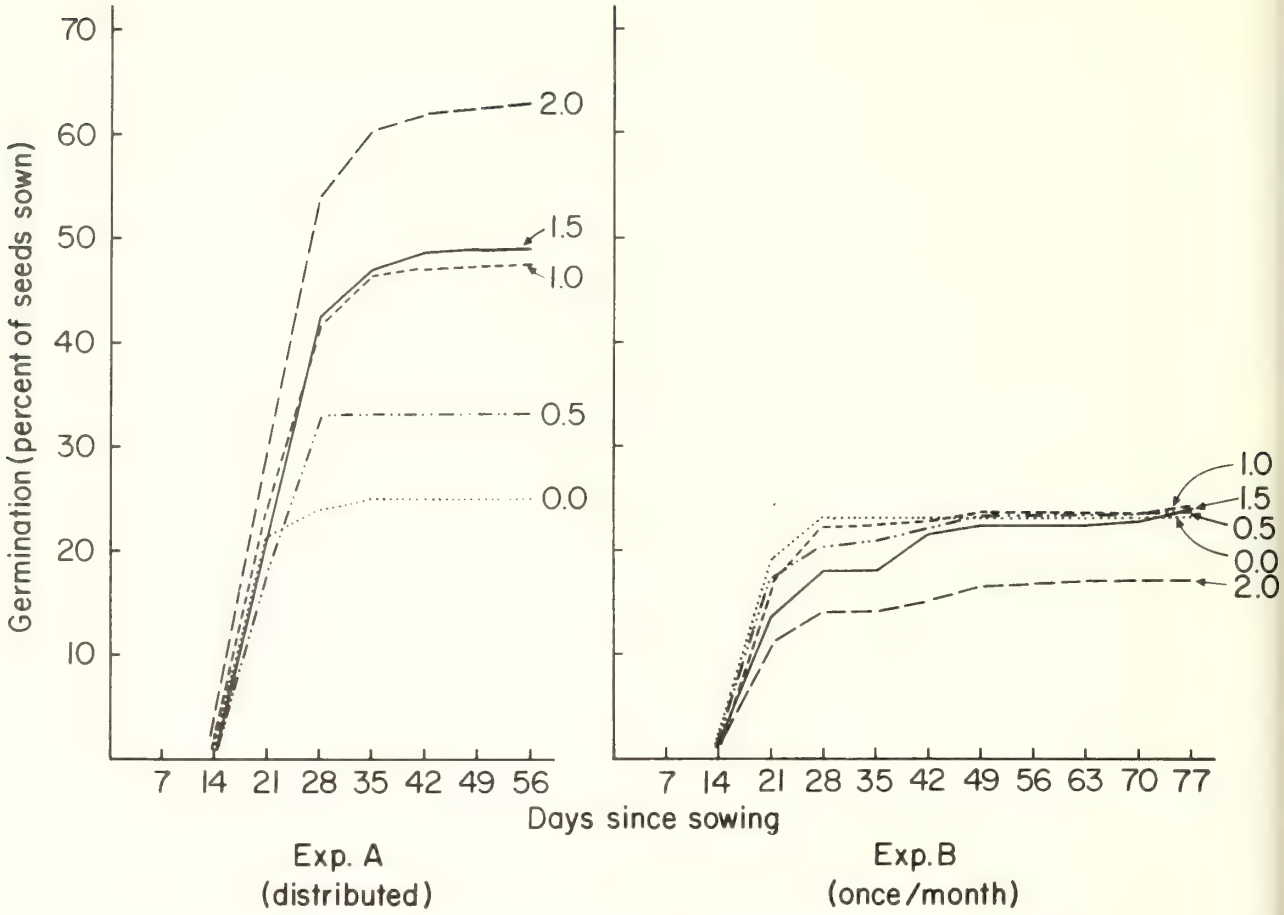


Figure 2.—Length of germination period in relation to water (Inches) amounts and distribution.

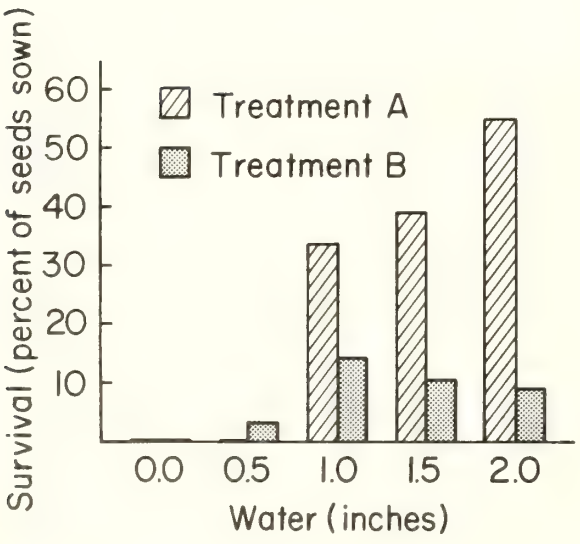


Figure 3.—Seedling survival after 20 weeks in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

When water was applied once a month, seedling growth was not significantly affected by amount of water received except at 2.0 inches/month, where seedlings were taller and root/shoot ratios were smaller ($\alpha = 0.05$, table 2).

Discussion and Conclusions

The greenhouse environment was more favorable to germination, survival, and growth than natural conditions. It is difficult, therefore, to extrapolate results from the greenhouse to the field. Nevertheless, certain inferences can be drawn from these experiments, combined with observations in the field, concerning the effects of amount and distribution of precipitation on natural regeneration of Douglas-fir in the central and southern Rocky Mountains.

Assuming that adequate seed is available and seedbed conditions are favorable, more seedlings

Table 1.— Percent total mortality, by cause, of greenhouse-sown Douglas-fir seedlings watered at predetermined intervals during the month (A); and watered once a month (B).

Monthly amount of water		Drought		Damping-off		Failure to establish		Other causes	
		A	B	A	B	A	B	A	B
in	*cm*								
0.0	(0.0)	98.6	92.8	1.4	1.4	0.0	5.8	0.0	0.0
0.5	(1.3)	94.0	76.3	3.0	5.1	3.0	16.9	0.0	1.7
1.0	(2.5)	87.5	69.0	5.0	13.8	7.5	17.2	0.0	0.0
1.5	(3.8)	46.7	63.1	30.0	31.6	13.3	5.3	10.0	0.0
2.0	(5.1)	20.8	58.3	33.3	25.0	29.2	16.7	16.7	0.0
Aver.		82.0	74.0	9.2	13.9	7.3	11.7	1.5	0.4

emerge with frequent showers than with one or two larger storms. At least 1 inch per month or more of well-distributed rainfall is necessary to provide adequate germination; whereas, if monthly rainfall is poorly distributed, germination is inadequate even at 2 inches per month (fig. 1). Most germination is completed in 30 days, whether precipitation is well distributed or occurs in only one or two storms (fig. 2).

At least 1 inch of evenly distributed precipitation is needed each month before seedlings survive in significant numbers and additional rainfall further increases survival. However, seedling survival is inadequate with infrequent precipitation even at 2 inches per month (fig. 3).

Distribution of precipitation does not seem to have an important effect on size and biomass of Douglas-fir seedlings that survive the first growing season. However, the amount of rainfall can affect seedling growth since, at 2 inches of rainfall per month, seedling biomass was greater with well-distributed precipitation, and seedlings were taller when water was applied as in one major storm per month. However, these seedling growth measurements are probably not comparable to field-grown seedlings, since average top height was about 1½ times and root length about 2½ times greater than field-grown, first-season seedlings (Jones 1971).

In this study, precipitation has been considered as an independent variable. Regeneration success is affected by many other environmental factors and their interactions, which must be evaluated before the effectiveness of a single factor such as precipitation can be fully analyzed. It is apparent, however, that under certain conditions, the amount and distribution of precipitation can be a major factor in the establishment of Rocky Mountain Douglas-fir seedlings.

Table 2.— Average growth of greenhouse-grown Douglas-fir seedlings watered at predetermined intervals during the month, and watered once a month. (Means for each variable with common or no subscripts are statistically homogeneous at $\alpha = 0.05$)

Monthly water treatment	Dry weight		Seedling height		Root length		Root/shoot ratio	
	A	B	A	B	A	B	A	B
in	*mg*		*mm*		*mm*			
1.0	38.6a	45.0	37.9	39.0a	174.6	230.8	4.64	5.99a
1.5	50.1a	45.4	39.7	35.4a	191.3	232.1	4.84	6.66a
2.0	63.4b	46.5	39.7	41.8b	205.3	193.2	5.25	4.67b

Literature Cited

Graybill, Franklin A. 1976. Theory and application of the linear model. 704 p. Duxbury Press, North Scituate, Mass.

Hayes, G. Lloyd. 1965. Providing for optimum regeneration in the logging plan—east side. West. Refor. Coord. Comm. Vancouver, B.C.,[Dec. 1965 Proc. 1965:6-9. West. For. Conserv. Assoc., Portland, Oreg].

Jones, John R. 1967. Regeneration of mixed conifer clearcuttings on the Apache National Forest, Arizona. U.S. For. Serv. Res. Note RM-90, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

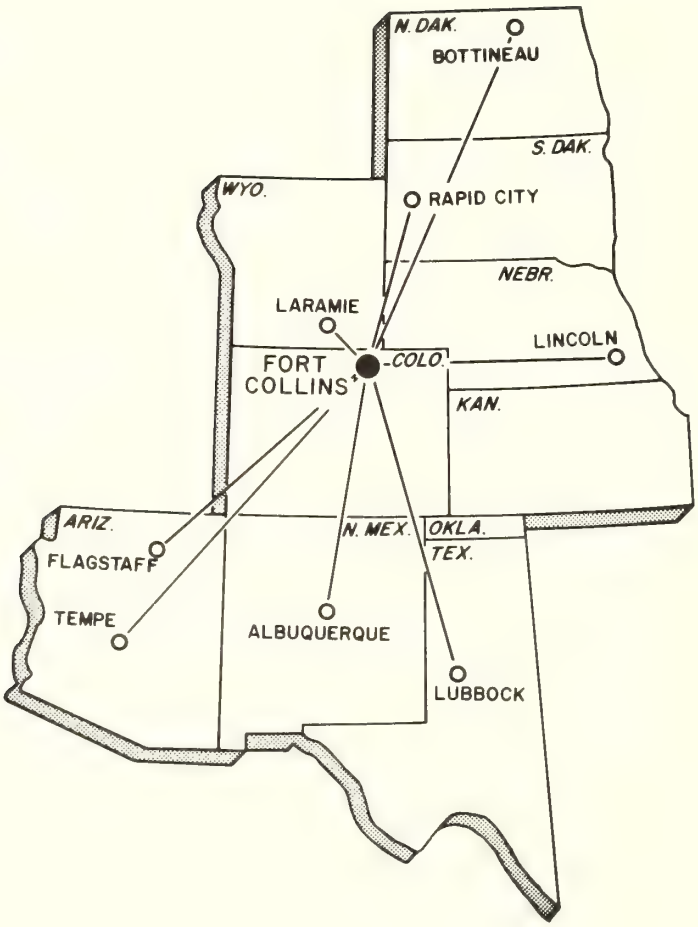
Jones, John R. 1971. Mixed conifer seedling growth in eastern Arizona. USDA For. Serv. Res. Pap. RM-77, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Krauch, Hermann. 1956. Management of Douglas-fir timberland in the Southwest. U. S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 21, 59 p.

Marcus, Steven R. 1973. Geology of the Montane Zone of central Colorado—with emphasis on Manitou Park. USDA For. Serv. Res. Pap. RM-113, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Oosting, Henry J. 1956. The study of plant communities. 440 p. W. H. Freeman and Co., San Francisco, Calif.

Ryker, Russell A. 1975. A survey of factors affecting regeneration of Rocky Mountain Douglas-fir. USDA For. Serv. Res. Pap. INT-174, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.


N. DAK.
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT
COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

t 1978

RESEARCH NOTE RM-358

REST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Biology and Control of Lilac Borer in the Northern Great Plains

M. E. Dix[1], A. D. Tagestad[1], D. G. Nielsen[2], and F. F. Purrington[2]

Life stages, seasonal history, impact, and control of lilac borer, *Podosesia syringae* (Harris) (Lepidoptera: Sesiidae) in green ash, *Fraxinus pennsylvanica* Marshall, of the northern Great Plains are described. For maximum control of shelterbelt and landscape trees, insecticides should be applied 10-14 days after first emergence. A synthetic attractant can be used to monitor seasonal flight activity of male moths and trap capture data used to determine the most effective time to apply the insecticides.

UNIVERSITY LIBRARY DEC 1 5 1978

Green ash (*Fraxinus pennsylvanica* Marshall), is a long-lived, winter-hardy, alkali-and drought-resistant broadleaf found both in native stands and in farm, field and urban plantings on the Great Plains. Trees are frequently infested with lilac borers[3], *Podosesia syringae* (Harris) (Lepidoptera: Sesiidae), a moth whose larvae construct galleries in wood beneath the bark. In a 1972 survey of green ash in 96 North Dakota field and farmstead windbreaks, lilac borer was present in 51% of the plantings and infested 3.5% of the trees in these plantings (Tunnock and Tagestad 1973). In a 1976 survey of 116 green ash shelterbelts in North Dakota, 41% of the shelterbelts and 3.8% of the green ash were infested[4].

Lilac borer may infest as much as 50% of the green ash in urban plantings (Peterson 1971). In August 1977, 33% of the boulevard green ash trees in Grand Forks were infested with lilac borers[5]. Lilac borer infestations have recently been reported in Pierre, S. Dak., and Bismarck and Minot, N. Dak.[6 7] Severe borer damage often results in wind breakage, general decline in tree vigor, decreased esthetic value, or tree mortality.

Description of Life Stages

The adult is a day-flying, wasp-like moth with transparent hind wings, slender abdomen, and

[1]*Research entomologist and biological technician, respectively, Rocky Mountain Forest and Range Experiment Station, located at the Station's research work unit at Bottineau, in cooperation with North Dakota State University. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Research Entomologist and Technician, respectively, Department of Entomology, Ohio Agricultural Research and Development Center, Wooster, Ohio 44691.*

[3]*This is the approved common name of the insect called ash borer in the Great Plains and the South.*

[4]*Flavel, T. H., A. D. Tagestad, S. Sladek, and M. E. Dix. A 1976 survey to evaluate wood borers in green ash windbreaks in North Dakota. USDA For. Serv. Div. State and Private For. R-1. Missoula, Montana. In preparation.*

[5]*Staley, J. 1977. City Forester. Grand Forks, N. Dak. Personal communication.*

[6]*Suedkamp, J. 1977. South Dakota Game and Fish Department, Pierre. Personal communication.*

[7]*Blackwell, G. 1977. City Forester. Bismarck, N. Dak. Personal communication.*

Figure 1.—Typical lilac borer damage in green ash.

Figure 2.—Lilac borer moth [*Podosesia syringae* (Harris)].

Figure 3.—Eggs of lilac borer.

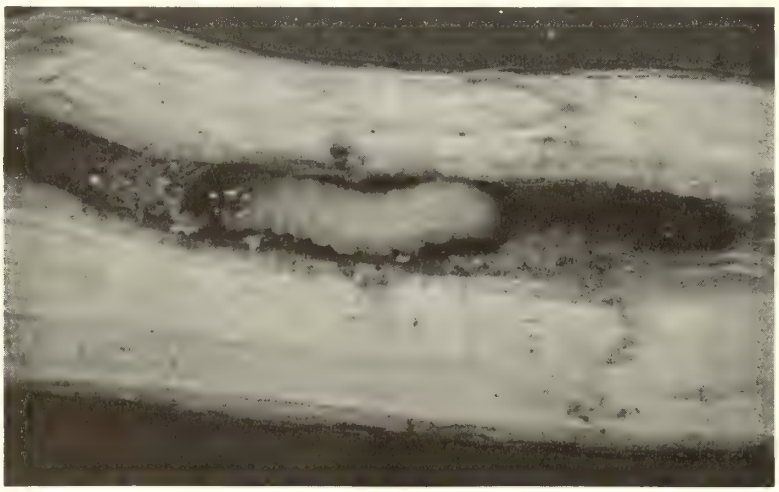


Figure 4.—Lilac borer larvae in gallery.

Figure 5.—Lilac borer pupa in larval gallery. Note emergence flap.

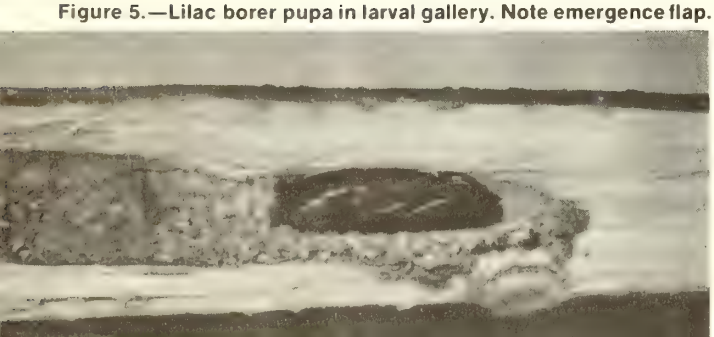


Figure 6.—Pupal skin left by emerging lilac borer moth.

very long yellow and black hind legs (fig. 1). Color varies from yellow to brown-black. The Bowman County form has several wide yellow bands on its abdomen while the Turtle Mountain (Bottineau County) form has several indistinct orange or reddish orange bands on the abdomen. The wings of all lilac borers are narrow and span 25 to 35 mm.

The eggs are tan, elliptical in shape, about 0.7 mm long and 0.4 mm wide (Solomon 1975, Purrington and Nielsen 1977) (fig. 2).

Newly hatched larvae are white with an amber-colored head and about 1 mm long. Mature larvae are about 26 mm long, creamy white with a shiny brown head (fig. 3).

The tan to reddish-brown pupa is 18-24 mm long with small backward projecting spines on the abdomen (Solomon 1975, Anonymous 1971) (fig. 4). Its skin remains protruding from the tree following adult emergence (fig. 5).

Life Cycle

Lilac borer occurs from the Atlantic Ocean to the Rocky Mountains of the United States and Canada (Purrington and Nielsen 1977). All populations studied in the United States have a 1-year life cycle. Peterson (1971) reports a 2-year life cycle in Canada. In North Dakota, the moths usually emerge from May through July with a peak in June. The female emits a potent airborne scent, known as a sex pheromone, that attracts males (Nielsen and Balderston 1973). Very minute amounts of the sex attractant (Z,Z)-3, 13-octadecadien-1-ol acetate (Nielsen et al. 1975) can attract males over a distance of at least half-a-mile. After mating, the female lays eggs on the bark surface, especially in cracks and crevices of old wounds. Ten to 14 days later the larvae hatch and bore into the tree. Young larvae initially "mine" just beneath the bark and later "mine" into the sapwood. Entrances to new galleries are marked by frass—a mixture of fine boring dust, oozing sap and body wastes. Older galleries are marked by larger clumps of frass which collect at the irregular entrance hole, in bark crevices below the hole, or on the ground at the base of the tree. During the summer, larvae continue to feed and extend their tunnels first horizontally into the sapwood, then upwards until they bore to within a few millimeters of the bark late in the season. Completed tunnels are about the width of a pencil (5-7 mm) and vary from 7-32 cm in length. Larvae overwinter in the heartwood. Prior to pupating the following spring they construct an emergence hole in the bark (fig. 4). The pupa uses the backward projecting spines to wriggle forward, break the bark, and push partially out the exit hole. When the moth emerges, the pupal skin is left in the exit (Peterson 1971, Solomon 1975) (fig. 6).

Control

Parasites, predators, and diseases are natural enemies of lilac borer larvae and adults. During the summer the wasps *Macrocentrus marginator* (Nees) and *Apanteles* sp. locate and parasitize larvae. The fungus *Beauvaria bassiana* (Bals) Vuillmon, may also occur in the galleries and kill larvae. During the winter and spring, woodpeckers destroy large numbers of larvae and pupae. Although these natural controls reduce lilac borer population, they will not control it.

Silvicultural practices which improve tree vigor may reduce borer survival or enable trees to withstand attack. These practices include cultivation to control competing vegetation, irrigation to decrease effects of drought, thinning to remove competing, diseased, and dead trees, and pruning to remove weakened, diseased, injured, or dead branches. Every effort should be made to maintain tree vigor while the trees are young and more vulnerable to lilac borer damage.

The insecticides Dursban[R] (0.5%)[8] and lindane (0.5%) are registered for control of lilac borer in green ash. Only registered commercial applicators can apply Dursban. The insecticides are mixed with water according to the directions on the label and then sprayed to runoff on the trunk and all branches below a height of 2 m. Gallery entrances, rough areas and wounds should be thoroughly sprayed. A compress air sprayer or a hydraulic sprayer may be used to apply the insecticide. Contact your county extension agent or land grant university for additional information on insecticides and their application.

The insecticides kill newly hatched larvae before they become established in trees. For

[8] *Trade names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

maximum effectiveness, they must be sprayed on the lower trunk and branches approximately 10-14 days after first adult emergence. In North Dakota, first emergence of adult lilac borer varies from mid-May to early June. Consequently, a borer spray should be applied during the latter part of May or the first week in June. Timing can be pinpointed by monitoring male flight activity with pheromone traps. Traps suitable for this purpose are commercially available. Contact your county extension agent or your land grant university concerning trap availability.

During May, June, and July, 1975 and 1976, emergence of lilac borer males was monitored in four multi-row shelterbelts surrounding the U.S. Army Corps of Engineers Bowman-Haley Reservoir in Bowman County, North Dakota, and in mixed hardwood stands of the Turtle Mountains in Bottineau County, North Dakota. In 1975, we baited sticky traps with rubber septa dispensers containing a synthetic attractant. In 1976, traps were baited with Conrel[8] hollow-fiber dispensers containing the attractant (fig. 7). The 25 traps at the Bowman-Haley

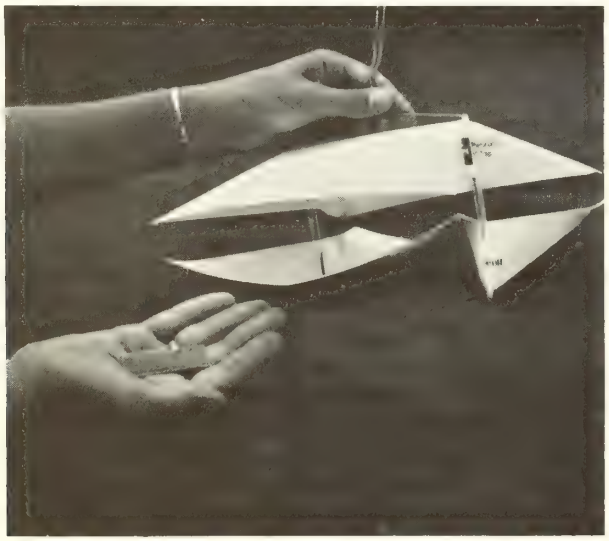


Figure 7.—Pherocon 1C trap and conrel dispenser containing (Z,Z)-3,13-octadecadien-1-o1 acetate.

Reservoir and 10 traps in the Turtle Mountains were positioned on the green ash trees about 1 m above the ground. Traps were changed and trap catches recorded every 2 weeks in Bowman County and biweekly in Bottineau County.

The 1975 Bowman County flight began in mid-June and peaked at an average 18.8 males per trap prior to June 24. Emergence in Bottineau County began the third week in June and rose to an average 10 males per trap on July 3. Trap capture then dropped to an average 5.1 males per trap by July 9, because of low temperatures, but regained an average of 11 males per trap by July 15. In 1976, lilac borer emergence in Bowman and Bottineau Counties began and peaked two weeks earlier than in 1975, a circumstance which can also be attributed to warmer temperature patterns.

For maximum protection of shelterbelt and landscape green ash trees, insecticides should be applied 10-14 days after first emergence (trap capture) of male lilac borers. For example, in Bowman County, borers first emerged on May 26, 1975. Consequently, insecticides should have been applied to green ash trees between June 5 and 9. In 1976, first emergence occurred on May 11. The trees should have been sprayed between May 21 and 25.

Literature Cited

Nielsen, D. G., and C. P. Balderston. 1973. Evidence for intergeneric sex attraction among aegeriids. Ann. Entomol. Soc. Am. 66:227-228.

Nielsen, David G. and Foster F. Purrington. 1974. Flight periods of *Podosesia* and comments on the monotypic status of the genus (Lepidoptera: Sesiidae). Ann. Entomol. Soc. Am. 67:959-960.

Nielsen, D. G., F. F. Purrington, J. H. Tumlinson, R. E. Doolittle, and C. E. Yonce. 1975. Response of male clearwing moths to caged virgin females, female extracts and synthetic sex attractants. Environ. Entomol. 4:(3):451-454.

Peterson, L. O. T. 1971. Control of borers in planted trees in the prairie provinces. Can. Dep. Reg. Expans. P.F.R.A. Tree Nursery, Indianhead, Sask. T.N. Pam. No. 2. (rev.) 15 p.

Purrington, Foster Forbes, and David G. Nielsen. 1977. Biology of *Podosesia* (Lepidoptera: Sesiidae) with description of a new species from North America. Ann. Entomol. Soc. Am. 70:(6)906-910.

Solomon, J. D. 1975. Biology of an ash borer, *Podosesia syringae* in green ash in Mississippi. Ann. Entomol. Soc. Am. 68:325-328.

Tunnock, Scott, and Arden Tagestad. 1973. Incidence of wood borer activity in green ash windbreak plantings in North Dakota. USDA For. Serv. Div. State & Private For. R-1. Missoula, Mont. 13 p.

ember 1976

RESEARCH NOTE RM-359

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Range Cattle Impacts on Stream Water Quality in the Colorado Front Range

Steven R. Johnson, Howard L. Gary[1] and Stanley L. Ponce[2]

Studies on two adjacent pastures along Trout Creek in central Colorado indicated only minor effect of cattle grazing on water quality. Bacterial contamination of the water, however, significantly increased. Following removal of the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture.

CLEMSON UNIVERSITY LIBRARY
DEC 15 1976
DOC. TECH. SECTION GOVT. DEPOSITORY

Background

When cattle and other livestock are concentrated along small mountain streams, they are reported to impact the physical, chemical, and biological properties of the water. Excretion of body wastes in or near streams may add nitrogen and phosphorous compounds as well as pathogenic bacteria. Livestock trampling along streambanks may increase dissolved and suspended solids carried by streams. Heavy concentrations of cattle may also change water quality parameters to levels which will not only affect local use of water but may present health hazards to downstream users.

The purpose of this study was to determine the impact of range cattle over a short-term period on water quality, and to determine whether local grazing management practices should be changed. Data are presented for a 21-day period intensively sampled in June 1977 for the effect of 150 cows and calves concentrated along a stream typical of the Colorado Front Range.

Previous Studies

Several stream studies in Montana, Colorado, and Utah have reported the impact of grazing animals on wildland water quality (Darling 1973, Kunkle and Meiman 1967, Morrison and Fair 1966, Walter and Bottman 1967), but information on grazing effects in low-flow streams common to the Front Range of Colorado is limited. Kunkle and Meiman (1967) as well as Morrison and Fair (1966) found that bacterial counts were related to the proximity of grazing animals to the stream. Other studies have also indicated that concentrations of cattle on grasslands and pastures can contribute significant amounts of nitrogen and phosphorous compounds to surface waters,

[1]*Hydrologic technician and principal hydrologist, respectively, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. Station's central headquarters is located in Fort Collins, in cooperation with Colorado State University.*

[2]*Assistant professor, Department of Earth Resources, Colorado State University, Fort Collins.*

especially following rains and snowmelt runoff (Armstrong and Rohlich 1970, Oglesby 1971).

Study Area

The study was conducted along a 2.6-km section of Trout Creek, a perennial stream that flows through the Manitou Experimental Forest, about 13 km downstream and north of Woodland Park, Colo. The creek is a major tributary of the South Fork of the South Platte River.

The study area consisted of two adjacent pastures, each bisected by Trout Creek (fig. 1). The upper pasture was not grazed. The lower grazed pasture had 85 ha of grazable land, and the cattle had unrestricted use of the area. Each pasture had about 1.28 km of stream channel.

The flood plain in each pasture was composed of unconsolidated and coarse textured alluvium, derived from Pikes Peak granite. Unstable and easily erodable streambanks up to 2 m high are common to the area. The flood plain vegetation (about 10% of the area) consisted mainly of willows, sedges, rushes, buttercups, irises, Kentucky bluegrass, white clover, common dandelions, and various stages of weed succession (fig. 2). Vegetation in the dry upland area was mainly bunchgrass (Arizona fescue and mountain muhly) and open ponderosa pine forests.

Mean elevation of the area was about 2,357 m. Average annual precipitation is about 400 mm, with two-thirds of this amount falling during the growing season from April through September. Streamflow for the study section of Trout Creek ranges from about 0.28 m^3/sec in the spring to a low of 0.01 m^3/sec in late summer.

About 30 beavers were removed from the control pasture during the previous winter, and seven major beaver dams were breached 1 month prior to water sampling. The drained beaver ponds left broad silt flats and contributed varying amounts of sediment and organic debris to the stream. Beavers were not present in the lower

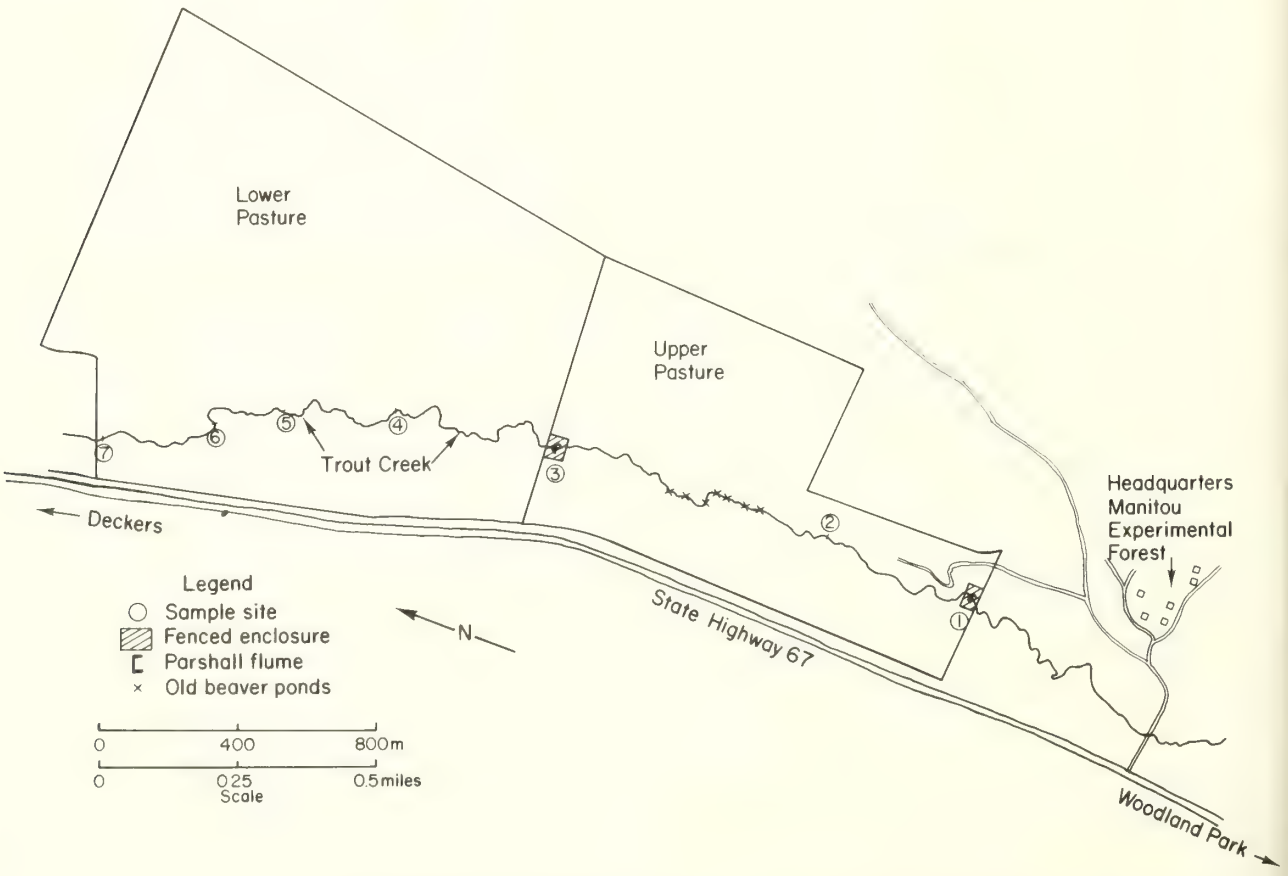


Figure 1.—Location of pastures, sampling sites and physical features of the study.

the upland

ı pastures
and have
pril until
emainder
ıt Creek.

ves were
ril 1977.
e control

lyzed on
d on five
ure was
control
pasture.
lined in
alth As-
ed oxy-
d total
y, am-
al coli-
counts.
e their
ttle ac-
several

wo 48-
stage
xygen
(EC)

were measured on-site with battery operated meters. Grab samples of water were collected in sterile polyethylene bottles for all other analyses. All sampling was done during the morning, and water samples were kept iced until processing.

ERRATA SHEET

The following error has been noted in Research Note RM-359, "Range cattle impacts on stream water quality in the Colorado Front Range."

p. 4, left column, line 12, "July 10" should be "June 10".

Suspended and total dissolved solids (SS and TDS) were determined gravimetrically. Ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and orthophosphate (PO_4) measurements were made colormetrically following filtration to remove turbidity interference. The respective tests were made using prepackaged reagent powder pillows along with other reagents. Bacterial culturing was routinely completed within 2 hours of the first sample collection using the membrane filter technique and several dilutions per sample.

All data were analyzed using a two-way analysis of variance of pastures and sampling days. Minimum significance for acceptance of hypothesis of no difference was the 0.05 level. Comparison of pooled pasture means (sites 1, 2, 3 and sites 4, 5, 7) were made both during and after the grazing period as a test of grazing effects. Data from sites 5 and 6 were averaged to balance the variance analysis.

Results and Discussion

Cattle Activities

The cattle generally grouped along the flood plain within about 400 m of the stream during the day, but tended to disperse and move into the warmer uplands at night. Visual observations during this and in other studies indicated the cattle generally spent considerably less than 1% of the day in the stream drinking or resting (Dwyer 1961). Thus, the probability of elimination of body wastes into the stream was low.

Stream Temperature and Dissolved Oxygen

Stream temperatures generally ranged between 13° and 18°C during sampling. The range was mainly due to an hour time lapse between collection of the first and last water samples. Dissolved oxygen, because of the turbulent nature of the stream, was at or near saturation for all sites for the duration of the study.

Suspended Solids and Streamflow

High concentrations of suspended solids (SS) are generally an indication of erosion and are usually associated with the degree of impact of man's activities. Waters having average SS concentrations above 80 mg/l generally harm fish and other aquatic life (McKee and Wolf 1963). The most common sources of SS in the local area were ero-

especially following rains and snowmelt runoff (Armstrong and Rohlich 1970, Oglesby 1971).

Study Area

The study was conducted along a 2.6-km section of Trout Creek, a perennial stream that flows through the Manitou Experimental Forest, about 13 km downstream and north of Woodland Park, Colo. The creek is a major tributary of the South Fork of the South Platte River.

The study area consisted of two adjacent pastures, each bisected by Trout Creek (fig. 1). The upper pasture was not grazed. The lower grazed pasture had 85 ha of grazable land, and the cattle had unrestricted use of the area. Each pasture had about 1.28 km of stream channel.

The flood plain in each pasture was composed of unconsolidated and coarse textured alluvium, derived from Pikes Peak granite. Unstable and easily erodable streambanks up to 2 m high are

common to
(about 10%
willows, se
tucky blue
lions, and
2). Vegetat
bunchgrass
and open p

Mean ele
Average a
with two-t
growing s
Streamflo
ranges fro
low of 0.01

About 3
trol pastu
seven maj
prior to
ponds left
ing amou
the strear

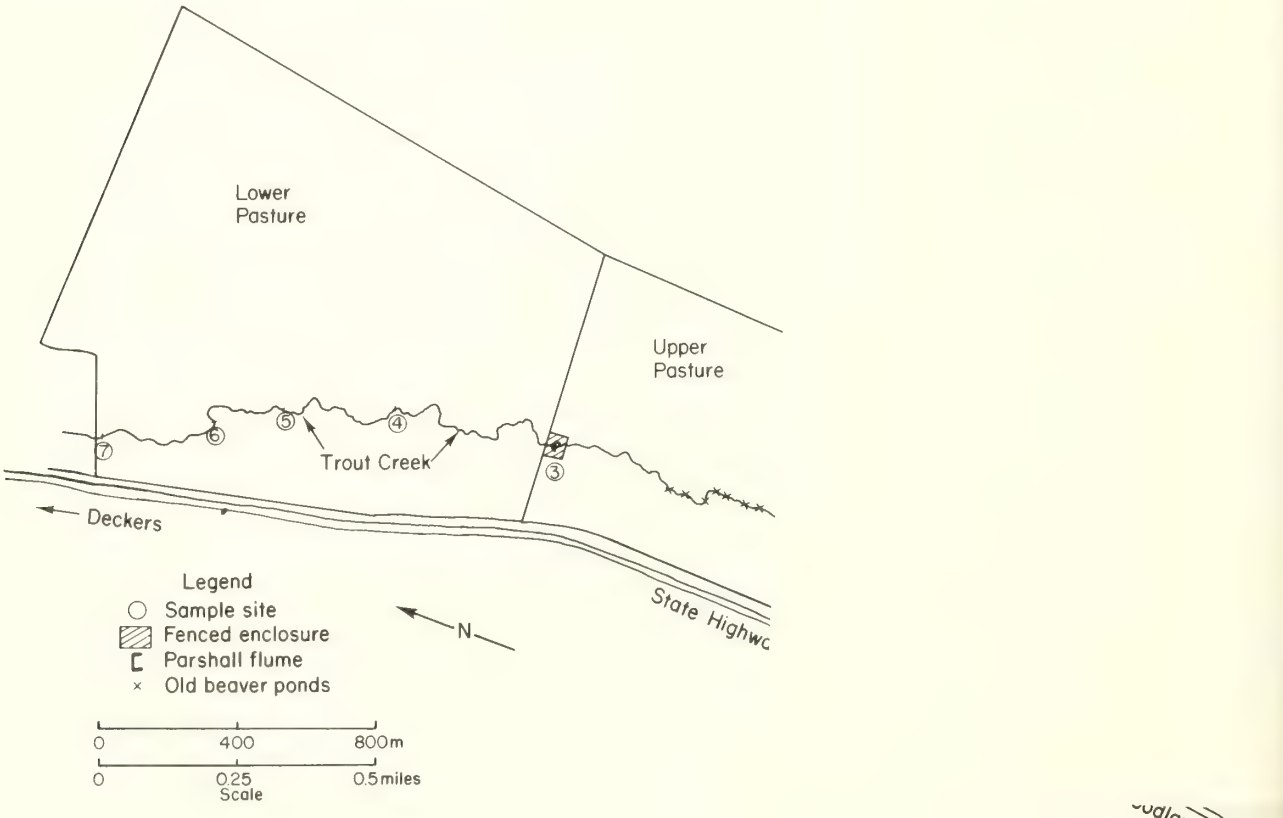


Figure 1.—Location of pastures, sampling sites and physical features of the study.

Figure 2.—The Trout Creek flood plain and the upland forest.

pasture. For the past several years, both pastures have been used only as holding areas and have been stocked with cattle from mid-April until early June, with no grazing use for the remainder of the year. The only water source is Trout Creek.

Methods

For this study, 75 cows plus 75 calves were placed in the lower pasture in early April 1977. The nearest livestock upstream from the control (ungrazed) pasture was about 3.2 km.

Water samples were collected and analyzed on six days during grazing (June 2 to 14) and on five days (June 16 to 24) when neither pasture was grazed. Three sites were sampled in the control pasture and four in the lower treatment pasture. Water analyses followed procedures outlined in *Standard Methods* (American Public Health Association, Inc. 1975) and included: dissolved oxygen, stream temperature, suspended and total dissolved solids, electrical conductivity, ammonia, nitrates, orthophosphates, and fecal coliform and fecal streptococci bacterial counts. These parameters were selected because their levels generally indicate water quality. Cattle activities and locations were observed on several days.

Stream discharge was also measured in two 48-inch Parshall Flumes equipped with stage recorders. Stream temperature, dissolved oxygen (DO), and specific electrical conductivity (EC) were measured on-site with battery operated meters. Grab samples of water were collected in sterile polyethylene bottles for all other analyses. All sampling was done during the morning, and water samples were kept iced until processing. Suspended and total dissolved solids (SS and TDS) were determined gravimetrically. Ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and orthophosphate (PO_4) measurements were made colormetrically following filtration to remove turbidity interference. The respective tests were made using prepackaged reagent powder pillows along with other reagents. Bacterial culturing was routinely completed within 2 hours of the first sample collection using the membrane filter technique and several dilutions per sample.

All data were analyzed using a two-way analysis of variance of pastures and sampling days. Minimum significance for acceptance of hypothesis of no difference was the 0.05 level. Comparison of pooled pasture means (sites 1, 2, 3 and sites 4, 5, 7) were made both during and after the grazing period as a test of grazing effects. Data from sites 5 and 6 were averaged to balance the variance analysis.

Results and Discussion

Cattle Activities

The cattle generally grouped along the flood plain within about 400 m of the stream during the day, but tended to disperse and move into the warmer uplands at night. Visual observations during this and in other studies indicated the cattle generally spent considerably less than 1% of the day in the stream drinking or resting (Dwyer 1961). Thus, the probability of elimination of body wastes into the stream was low.

Stream Temperature and Dissolved Oxygen

Stream temperatures generally ranged between 13° and 18°C during sampling. The range was mainly due to an hour time lapse between collection of the first and last water samples. Dissolved oxygen, because of the turbulent nature of the stream, was at or near saturation for all sites for the duration of the study.

Suspended Solids and Streamflow

High concentrations of suspended solids (SS) are generally an indication of erosion and are usually associated with the degree of impact of man's activities. Waters having average SS concentrations above 80 mg/l generally harm fish and other aquatic life (McKee and Wolf 1963). The most common sources of SS in the local area were ero-

sion from bank sloughing and from abandoned and washed out beaver dams.

In the present study, the innumerable stream crossings by cattle between sites 4 to 7 did not significantly increase SS (table 1). SS concentrations ranged from 3 to 183 mg/l. The source of SS was mainly the silt and organic debris stored in the former beaver ponds between study sites 2 and 3 in the upper pasture (fig. 3). Sites 1 and 2 in the upper pasture showed relatively low levels of SS for the period of grazing. The high SS shown for the grazed pasture on July 10, during peak streamflow, evidently originated from the former beaver dams in the upper pasture. The high amounts of SS were apparently transported downstream and through the grazed pasture, and there was little evidence the cattle further added significant amounts of SS in the period of high streamflow.

Following grazing, streamflow averaged about 0.06 m^3/sec, and SS were generally less than 10 mg/l at all sites except for site 3, which averaged about 15 mg/l. It will probably be a few years before all sediments are flushed out and/or stabilized in the beaver pond areas between sites 2 and 3.

Total Dissolved Solids and Specific Conductance

All natural stream waters contain dissolved solids. Common ions in solution include carbonates, bicarbonates, chlorides, sulfates, phosphates, and nitrates of calcium, magnesium, sodium and potassium. Total dissolved solids (TDS) and specific electrical conductivity (EC) of natural waters are lowered by rainfall or snowmelt water (Tiedeman 1974) and raised by the addition of wastewater effluents, and runoff from feedlots and fertilized fields and pastures.

In this study, TDS were considerably less than the lower threshold value of about 400 mg/l reported for productive waters (McKee and Wolf 1963). The cattle had no significant effect on TDS or EC during the period of grazing. The significant difference in TDS between pastures after grazing (table 1) may indicate that some livestock waste products eventually reached and enriched the stream, probably from the action of rain showers.

Ammonia and Nitrate Nitrogen

In rural areas, much like the study area, NH_3-N and NO_3-N generally originate either from leakage of septic tanks and effluents from waste treatment plants, runoff from barnyards and feedlots, or runoff from fertilized pastures and croplands.

NH_3-N is readily oxidized to NO_3-N under aerobic conditions, and in unpolluted streams, concentrations are generally less than 0.2 mg/l (McKee and Wolf 1963). The average concentrations of NH_3-N for the periods of measurement on Trout Creek ranged from 0.26 to 0.29 mg/l in the ungrazed and grazed pastures respectively (table 1).

NO_3-N, the most completely oxidized and most stable form of nitrogen in surface waters, is a natural fertilizer and generally stimulates the growth of aquatic plants and increases fish production. Average concentrations of NO_3-N during

Table 1.—Mean values from the two pastures during and after grazing for selected water quality parameters.

Parameter	June 2 through June 14			June 16 through June 24		
	Upper pasture (no grazing)	Lower pasture (grazed)	Diff.	Upper pasture (no grazing)	Lower pasture (no grazing)	Diff.
Suspended solids (SS) mg/l	34.2	63.4	29.2	9.8	7.8	2
Total dissolved solids (TDS) mg/l	152	152	0	139	142	[2]3
Specific electrical conductivity (EC) μmhos/cm	209	211	2	221	224	3
Ammonia nitrogen (NH_4-N) mg/l	.26	.27	.01	.26	.29	.03
Nitrate nitrogen (NO_3-N) mg/l	.30	.36	.06	.13	.13	.00
Orthophosphates (PO_4) mg/l	.20	.22	.02	.20	.18	-.02
Fecal coliforms (FC) colonies/100 ml	20	105	[1]85	21	44	23
Fecal streptococci (FS) colonies/100 ml	73	176	[1]103	210	323	113

[1] *Statistically significant at 0.05 level*
[2] *Statistically significant at 0.01 level*

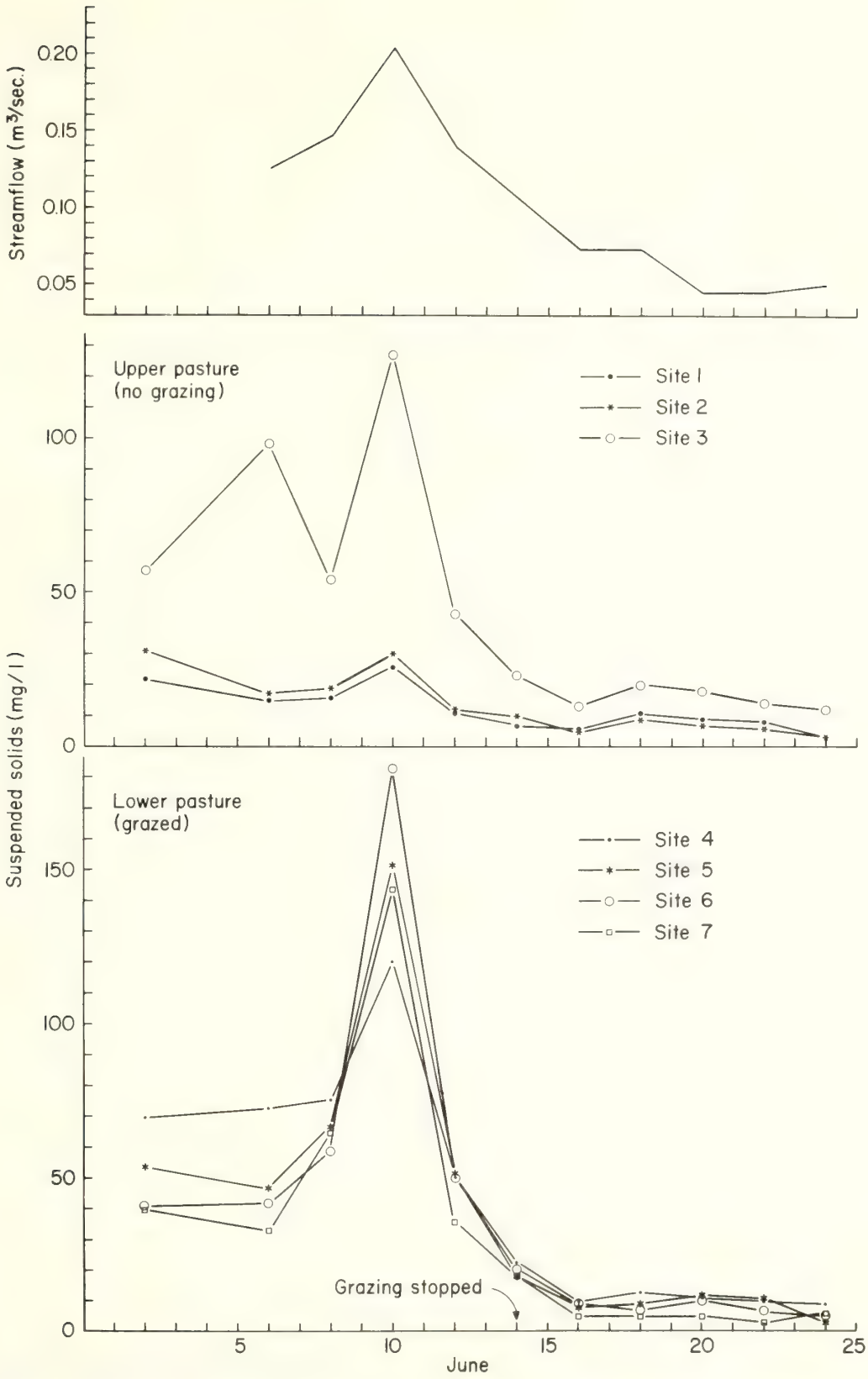


Figure 3.—Streamflow and suspended solids (SS) for each sampling site in the upper and lower pastures.

the period of grazing ranged from 0.30 to 0.36 mg/l in the ungrazed and grazed pastures, respectively (table 1). In the period of no grazing, the concentration of NO_3-N averaged 0.13 mg/l in both pastures (table 1). The higher nitrate concentrations during the period of grazing coupled with higher streamflow during the period were believed to indicate a spring "flush out" of accumulated nitrate compounds from upstream banks. The concentration of NO_3-N for both study periods was relatively low and appeared to indicate only minor input from upstream sources. The presence of cattle in the lower pasture did not significantly increase NO_3-N levels. All observed concentrations were well below the maximum permissible level of 10 mg/l of NO_3-N for domestic water supplies (U.S. Environmental Protection Agency 1975).

Orthophosphates

Phosphorous is also an essential nutrient for both plants and animals, but excessive amounts in stream and lake water may result in overabundant aquatic plant growth, such as algae blooms. The major sources of phosphorous, other than geologic weathering, are runoff from feedlots, excessive applications of phosphate fertilizers and insecticides, and sewage effluents (U.S. Environmental Protection Agency 1976). Detergents containing phosphates are a minor source of phosphorous pollution, but the use of phosphates in cleaning compounds is decreasing.

The presence of cattle in the lower pasture did not significantly increase the concentration of orthophosphates (table 1). The average concentration was about 0.2 mg/l in both pastures. Orthophosphate concentrations below 0.2 mg/l do not generally cause undesirable enrichment and aquatic plant growth in streams (McKee and Wolf 1963).

Bacteriologic Parameters

Bacterial tests of water pollution are usually performed by culturing and counting a group of bacteria known collectively as coliform bacteria. These bacteria are always present in intestinal tracts of warm blooded animals and are eliminated in large numbers in fecal waste. The indicator bacteria are not usually pathogenic themselves and do not generally multiply outside the intestines but are often found in the company of intestinal pathogens affecting man and other mammals. Thus, their presence indicates that intestinal waste products have reached a stream water supply. Water supplies containing coliform densities greater than one colony/100 ml are generally unacceptable for domestic use (U.S. Environmental Protection Agency 1975).

All species of animals have generally characteristic proportions of fecal coliform (FC) and fecal streptococci (FS). Thus, the FC/FS ratios have been established to identify the source of pollution as human or non-human warm-blooded animal polluted (Kenner et al. 1960). When the ratio is greater than about 2.5, the source of fecal organisms is predominantly human wastes. Ratios less than about 1.0 usually indicate that domestic livestock and other animals are the source of pollution.

The FC and FS counts and ratios from the present study are given in table 2. All FC/FS ratios were less than 1.0 and appear to indicate that bacterial contamination was derived from non-human sources. In both study periods, FC and FS counts in the upper ungrazed pasture were relatively high and suggested that bacterial pollution was mainly due to small mammals and birds, since no cattle or people were in the immediate upstream area. The presence of the grazing cattle significantly elevated the FC and FS counts over those observed in the ungrazed pasture (table 1). After removal of the cattle, both FC and FS bacterial counts dropped to statistically non-significant levels within the 9-day study period following grazing. Because of wide fluctuation in FS bacteria counts, there were also significant differences among sampling days following grazing. This was expected, since widely variable bacterial counts are characteristic of most wildland streams and are greatly affected by rainy periods (Kunkle and Meiman 1967).

Conclusions

In the last 100 years, most of the meadows along the perennial streams in the Front Range of Colorado have been heavily used by cattle and other livestock. Undoubtedly, due to the large numbers of animals (some 300,000 head in 1950 (Gary 1975)), the quality of most streams has been impacted to some degree by livestock waste products.

The measured physical and chemical properties of streamflow in this study indicated minor pollution from unknown upstream sources. These findings, however, do not provide significant evidence

Table 2 –Mean fecal coliform (FC) counts, fecal streptococci (FS) counts, and FC/FS ratios for the periods of grazing and no grazing

Date Sampled	Sites 1-3 Upstream control pasture[1]			Sites 4-7 Downstream grazed pasture[2]		
	FC	FS	FC/FS	FC	FS	FC/FS
	Colonies/100 ml			*Colonies/100 ml*		
6-2	3	52	0.058	58	119	0.487
6-6	14	52	.069	38	83	.458
6-8	38	100	.380	149	157	.949
6-10	41	77	.532	192	252	.762
6-12	7	88	.080	58	119	.487
6-14	19	66	.288	136	330	.412
6-15	All cattle removed from downstream pasture					
6-16	7	46	.152	37	128	.289
6-18	19	131	.145	84	552	.152
6-20	18	102	.176	25	163	.153
6-22	21	159	.132	21	188	.112
6-24	41	610	.067	55	585	.094

[1]*No cattle in pasture during study.*
[2]*150 cow-calves in pasture.*

of major long-term cumulative impairment of water quality due to past grazing practices in the area. The pasture comparisons provided some insight as to the immediate effects of grazing. At stocking rates of about 1.2 ha of usable pasture per cow plus calf pair, a rate locally common for short-term, seasonally grazed pastures, there were no statistically significant differences in the physical and chemical properties of the stream water that could be attributed to the grazing cattle. However, the cattle contributed significantly to the bacterial contamination of the stream, but after removing the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture within a short time.

Today, range cattle (cows) number only about 122,000 head in the counties along the Front Range in Colorado or about 13% of the total number for the State.[3] Thus, the regional potential of livestock wastes contaminating streams along the Front Range has also been greatly reduced from earlier years and permanent removal of the cattle from the productive live stream flood plains does not appear justified.

Literature Cited

American Public Health Association, Inc. 1975. Standard methods for the analysis of water and wastewater. 14th ed. 874 p. Am. Public Health Assoc., Inc., New York, N.Y.

Armstrong, D. E. and G. A. Rohlich. 1970. Effects of agricultural pollution on eutrophication. p. 314-330. *In* Agricultural practices and water quality. T. E. Willrich and G. E. Smith, eds., Iowa State Press, Ames.

Darling, L. A. 1973. The effects of livestock grazing on wildland water quality. M.S. Thesis, Utah State Univ., Logan. 99 p.

Dwyer, D. D. 1961. Activities and grazing preference of cows and calves in northern Osage County, Oklahoma, Okla. Agric. Exp. Stn. Bull. B–588, 61 p. Stillwater.

Gary, Howard L. 1975. Watershed management problems and opportunities for the Colorado Front Range ponderosa pine zone: The status of our knowledge. USDA For. Serv. Res. Pap. RM-139, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Kenner, B. S., H. F. Clark and P. W. Kabler. 1960. Fecal streptococci. 1. Quantification in feces. Am. J. Public Health 50:1553–1559.

Kunkle, Samuel H. and James R. Meiman. 1967. Water quality of mountain watersheds. Colo. State Univ. Hydrol. Pap. No. 21, 53 p. Colo. State Univ., Fort Collins.

McKee, Jack Edward and Harold W. Wolf, eds. 1963. Water quality criteria. Calif. State Water Resour. Control Board, Publ. 3-A (revised) 548 p. Sacramento.

Morrison, S. M. and J. F. Fair. 1966. Influence of environment on stream microbial dynamics. Colo. State Univ. Hydrol. Pap. No. 13, 21 p. Colo. State Univ., Fort Collins.

[3]*Personal communication with Dr. C. K. Gee, USDA Economic Research, February 1978, Fort Collins, Colo.*

Oglesby, R. T. 1971. Farm land runoff. p. 15-19. *In* Agricultural wastes; Principles and guidelines for practical solutions. Cornell Univ. Conf. on Agric. Waste Manage. [Syracuse, N.Y., Feb. 11-12, 1971] Cornell Univ., Ithaca, N.Y.

Tiedemann, R. A. 1974. Stream chemistry following a forest fire and urea fertilization in North Central Washington. USDA For. Serv. Res. Pap. PNW-203, 20 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

U.S. Environmental Protection Agency. 1975. Interim primary drinking water stands. Fed. Regist. 40(51):11990-11998. Washington, D. C.

U.S. Environmental Protection Agency. 1976. Water quality and pollutant source monitoring: Field and laboratory procedure training manual, EPA-430/1-76-010. U.S. Environ. Protect. Agency, Off. of Water Program Oper., Cincinnati, Ohio.

Walter, W. G., and R. P. Bottman. 1967. Microbiological and chemical studies of an open and closed watershed. J. Environ. Health 30:157-163.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Agriculture — CSU, Fort Collins

er 1978

RESEARCH NOTE RM-360

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Dead Trees Used by Cavity-Nesting Birds on the Fraser Experimental Forest: A Case History

Virgil E. Scott, Jill A. Whelan,[1] and Robert R. Alexander[2]

UNIVERSITY LIBRARY
FEB 27 1979
COLO. STATE U.
FT. COLLINS

A total of 1,722 lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) snags were surveyed for cavity-nesting bird use on the Fraser Experimental Forest in Colorado. Broken-top snags greater than 12 inches d.b.h. had the highest percentage of bird use. Holes were also found in live trees with broken tops and scars. It is recommended that all broken-top snags greater than 8 inches d.b.h. be left standing for snag dependent wildlife and that live trees with broken tops or scars be left standing during timber harvest to insure future sites for cavity-nesting birds.

Dead trees (snags) serve a variety of purposes in natural timber stands. Many hole-nesting birds and mammals nest in snags, and ospreys (*Pandion haliaetus*) generally use snags for nesting structures. Snags are favorite perches for band-tailed pigeons (*Columba fasciata*), and are useful to raptors and fly-catching birds for hunting, feeding, and roosting perches. Red squirrels (*Tamiasciurus hudsonicus*) and some birds store food in snags, and woodpeckers feed on insect larvae in trunks of dead trees. Although the number of cavity-nesting birds in the subalpine zone may be lower than in some other timber types, they make up about 25% of the avian population.

[1]*Wildlife Research Biologist and Biological Technician, respectively, U.S. Department of the Interior, Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado, stationed at Fort Collins, Colo.*

[2]*Chief Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

In 1977, the U.S. Forest Service adopted a snag management policy to provide habitat needed to maintain viable, self-sustaining populations of cavity-nesting and snag-dependent wildlife species on the National Forests (U.S. Department Agriculture 1977). Recent emphasis on utilization of logging slash and standing dead trees for wood fiber (Bergstrom 1977, Wahlgren et al. 1977) may conflict with snag management goals. Since not all snags are suitable for both wildlife nesting sites and wood fiber, some trade-offs are possible. In addition, foresters need to know what kind of snags are used by wildlife and what trees will become snags suitable for wildlife.

Published information that will assist foresters in snag management is lacking. Scott et al. (1977) listed cavity-nesting birds of North America and summarized available information on distribution, food habits, and nest site requirements. McClelland and Frissell (1975)

described characteristics of snags used by birds in western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*) forests in Montana. Scott (1978) described ponderosa pine (*Pinus ponderosa*) snags used by birds in Arizona, but research is needed in other timber types and at other geographic locations because decay and standing time of snags will differ with climatic conditions.

METHODS

This study was conducted on the Fraser Experimental Forest, Colo. The forest has been described in detail by Alexander and Watkins (1977). Most snags inventoried were on study plots established to determine responses of nongame birds and small mammals to timber harvests. Additional spruce and fir snags were sampled outside the study plots. Plots were at approximately 10,000 feet elevation. Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) were the dominant overstory species in valleys and on north-facing slopes, while lodgepole pine (*Pinus contorta*) dominated southern exposures and ridges.

To characterize snags used by cavity-nesting birds, information was gathered on 1,078 lodgepole pine snags, 230 spruce snags, and 421 fir snags in the subalpine zone on the Fraser Experimental Forest.[3]

Information collected on snags 4 inches d.b.h. and larger included: d.b.h., condition of top (broken, etc.), relative size of branches, percent of bark present, condition of whitewood (solid or rotten), aspect, percent slope, and number of cavities. Each snag was examined with binoculars to determine bird use. Only those cavities that appeared to be true nest holes were counted. Snags with cone-shaped cavities or "starts" were not recorded as used.

RESULTS

Cavity-Nesting Birds Observed on the Study Area

Cavity-nesting birds observed on the study area during the breeding season included: mountain chickadee (*Parus gambeli*), western flycatcher (*Empidonax difficilis*), Williamson's sapsucker (*Sphyrapicus thyroidus*), common flicker (*Colaptes auratus*), red-brested nuthatch (*Sitta canadensis*), hairy woodpecker (*Picoides villosus*), brown creeper (*Certhia familiaris*), and black-capped chickadee (*Parus atricapillus*).

The cavity-nesting bird population was relatively low (48 pairs per 100 acres). There were 44 snags and 10 live trees per 100 acres indicating bird use. Most snags and live trees used were poor quality timber that could be left standing during harvesting with little loss of timber volume.

Charactersitics of Snags With Nest Holes

Diameter at Breast Height

Lodgepole pine.—Eighty-six percent of the lodgepole pine snags were less than 12 inches in diameter (table 1), but fewer than 1% showed evidence of use by cavity-nesting birds. The smallest snag found with a nesting hole was 6.5 inches in diameter. Eight percent of the snags greater than 11 inches d.b.h. had been used by cavity-nesting birds.

Subalpine fir.—Eighty-four percent of the fir snags were also less than 12 inches in diameter, and only 1% of these were used by cavity nesters. The smallest fir snag with a cavity was 10.2 inches d.b.h. In the larger diameter classes, 8% of the snags were used; the 16- to 19- and 20- to 23-inch classes had the highest use.

Spruce.—Forty-four percent of the spruce snags were in the 4- to 11-inch diameter classes, but only 2% were used by cavity-nesting birds. The smallest spruce snag found containing a nest hole had a diameter of 10.3 inches. Eighteen percent of the snags in classes larger than 11 inches d.b.h. contained cavities.

Broken Tops

Lodgepole pine.—Lodgepole pine snags with broken tops (fig. 1) were used more than those with intact tops (fig. 2). According to McClelland et al. (1975), the broken tops provide an avenue of entry for heart rot fungi (*Fomes* spp.), and development of heart rot was necessary to provide suitable nest sites for primary cavity nesters in live, broken-top larch

[3]*The authors wish to acknowledge the efforts and assistance of Peggy Svoboda and Steve Martin in collecting the data for this paper.*

Table 1.—Snag density and bird use of snags with broken and intact tops by size class

Species	Size class				Total	Density per acre
	Broken		Intact			
	4-11	12+	4-11	12+		
	--- Inches d.b.h.---					Number
Lodgepole pine						
With holes	4	9	4	3	20	0.16
Total	93	21	837	127	1,078	12.60
Percent	4.3	42.9	0.5	2.4	1.9	
Subalpine fir						
With holes	4	5	0	0	9	0.04
Total	56	24	299	42	421	3.50
Percent	7.1	20.8	0.0	0.0	2.1	
Spruce						
With holes	1	15	1	7	24	0.22
Total	25	41	75	81	223	3.50
Percent	4.0	36.6	1.3	8.6	10.8	
Total						
With holes	9	29	5	10	53	0.42
Total	174	87	1,211	250	1,722	17.70
Percent	5.2	33.3	0.4	4.0	3.1	

Figure 1.—Snags larger than 8 inches d.b.h. with tops broken off were usually selected as nest sites.

trees in Montana. Heart rot apparently is important in snags, since 9 to 21 broken-top snags larger than 11 inches d.b.h. had been used by cavity-nesting birds (table 1).

Subalpine fir.—All fir snags used by birds had broken tops, but those larger than 19 inches d.b.h. were used most often.

Spruce.—Spruce snags with broken tops were used more often than those with intact tops, and those greater than 11 inches d.b.h. showed the most use.

Other Characteristics

Bark retention, tree height, aspect, and branch condition were examined for all snags, but there were no differences in use based on these characteristics.

Live Trees Used

Nest holes were recorded in eight live lodgepole pine and two live spruce trees. With one exception, these nest holes were located in dead tops or in scars (fig. 3). One nest was found in the live wood of a broken-top lodgepole pine tree. Live trees used for cavity nests ranged from 9 to 20 inches d.b.h. and averaged 14.4 inches.

SUMMARY AND MANAGEMENT IMPLICATIONS

Cavity-nesting birds on the Fraser Experimental Forest used few of the available snags and live trees as nest sites. Those selected were usually larger than 8 inches d.b.h. and had broken tops. No other characteristics examined seemed to be important in nest site selection.

Scott (1978) found about 30% of the snags were lost during timber harvest in a ponderosa pine forest, and suggested that all snags be left standing except those that were safety hazards. In subalpine forests where snag density is high (17.7 per acre), all but one or two suitable snags per acre could be harvested without detriment to the cavity-nesting birds or raptors. Since some snags will be lost because of winds after timber harvest, all snags over 8 inches d.b.h. with broken tops should be left standing. Live trees with broken tops or scars should be left to provide future snags.

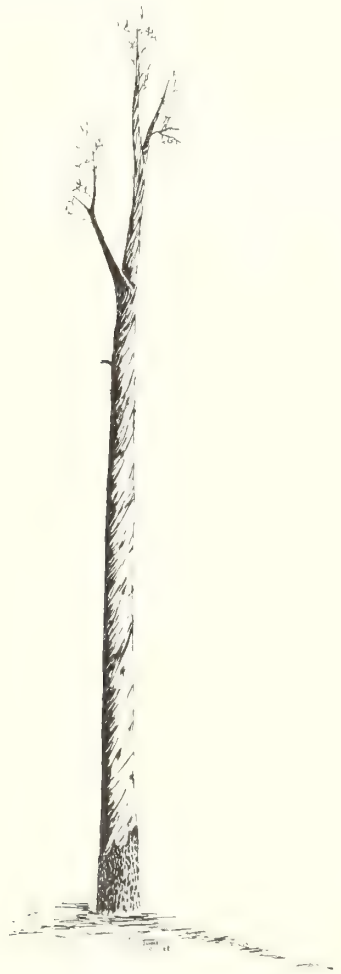


Figure 2.—Hard snags with intact tops were used significantly less than broken-top snags.

LITERATURE CITED

Alexander, Robert R., and Ross K. Watkins. 1977. The Fraser Experimental forest, Colorado. USDA For. Serv. Gen. Tech. Rep. RM-40, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Bergstrom, Dorothy. 1977. The legacy of the standing dead. *In* Forestry Research: What's New in the West. p. 5-8. (July 1977). USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

McClelland, B. Riley, and Sidney S. Frissell. 1975. Identifying forest snags useful for hole-nesting birds. J. For. 73(3):414-417.

Scott, Virgil E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. J. For. (76(1):26-28.

Scott, Virgil E., Keith E. Evans, David R. Patton, and Charles P. Stone. 1977. Cavity-nesting birds of North American Forests. U. S. Dep. Agric., Agric. Handbk. 511, 112 p.

U. S. Department of Agriculture, Forest Service. 1977. Forest Service Manual, Title 2630.3 (Policy), Wildlife Management.

Wahlgren, H. E., Roland Barger, and Harold Marx. 1977. Stretching our nation's timber supply-close timber utilization. USDA For. Serv. Program Aid 1189, 9 p.

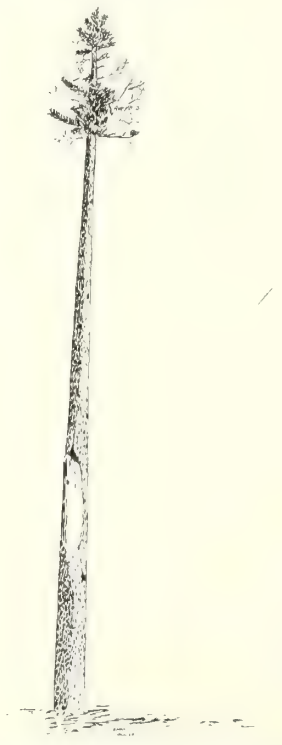


Figure 3.—Live trees with scars or broken tops also provided nest sites for cavity-nesting birds and can provide a source of future snags.

ber 1978

RESEARCH NOTE RM-361

REST SERVICE
. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The use of termites and other soil fauna to develop soils on strip mine spoils[1]

CLEMSON UNIVERSITY LIBRARY
JUN 11 1979
SCI., TECH. & AGR. DIV.

George Ettershank, Ned Z. Elkins, Perseu F. Santos, Walter G. Whitford, and Earl F. Aldon[2]

A laboratory study showed that soil arthropods, especially naturally occurring subterranean termites, can produce beneficial changes in the physical and chemical characteristics of mine spoil material.

Keywords: Soil arthropods, soil fauna, reclamation mine spoils.

Reclamation of spoils from the strip mining of oal in the arid Southwest currently consumes nuch water and energy. Current research is eeking ways of reducing these costs. Most urrent reclamation techniques are based on he establishment of native plant species. In reas of low rainfall, supplemental watering nd/or fertilization is used to maintain these pecies.

Undisturbed or natural soils contain bacria, fungi, and an assemblage of arthropods vhich make up the soil community. The soil community is a complex organization of interdependent species which process dead plant material and convert it into mineral soil, fix nitrogen, redistribute soil particles, enhance aeration, and generally affect the structure of a soil (Witkamp 1971). Mine spoils usually lack this biological soil community.

This implies that future management practices in mine spoil reclamation must be aimed at establishing a soil biota, as well as a supportive organic substrate for the soil organisms. The effect of the biota, working on organic material incorporated with the spoil, should be to create a soil environment conducive to vigorous and sustained plant growth.

Little is known about the structure of arid soil communities, and still less is known of the role soil arthropods play in maintaining that structure. To begin to understand this function, three studies were conducted to determine the structure of the soil arthropod community on unmined areas, compare those with mined areas, and measure arthropod populations of areas subjected to several reclamation practices on the Pittsburg and Midway Corp. McKinley Mine near Gallup, N. Mex.

[1]*The research reported here is a contribution to the SEAM rogram. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop and pply technology that will help maintain a quality environment nd other surface values while helping meet the Nation's ineral requirements. This research was supported by ontracts from SEAM and the New Mexico Energy Institute RB - 773203. The authors thank the Pittsburgh and Midway oal Company for providing study areas and materials.*

[2]*Ettershank is Research Professor, Elkins and Santos are raduate Students, and Whitford is Professor of Biology, New lexico State University, Las Cruces. Aldon is Principal ydrologist, Rocky Mountain Forest and Range Experiment tation, located at Station's Research Work Unit at lbuquerque, in cooperation with University of New Mexico; tation's central headquarters is maintained at Fort Collins, in operation with Colorado State University.*

Methods

Study 1

The density of colonies of the termite *Reticulitermes tibialis* Banks. naturally found on unmined areas near McKinley Mine was estimated on three standard bait unit-grids (toilet paper rolls — 100 rolls/grid in 10 rows of 10 baits at 1-m intervals). The areas sampled were in pinyon-juniper and sagebrush communities at an elevation of 2,130 m. These bait unit-grids were checked approximately monthly for termite activity, during visits to the site in the summers of 1977 and 1978.

Study 2

In September 1977, three bait rolls containing several hundred termites (*Reticulitermes tibialis* Banks.) were placed on top of three 2-liter cans of unamended mine spoil. The spoil material was moistened, and the container and roll were covered with aluminum foil to retain moisture. The containers were incubated at room temperature, 20° to 25° C, during the experiment. Two of the three containers had flourishing colonies of live termites when the experiment was terminated 9 months later, in June 1978. Spoil material without termites was held in a container in the same laboratory. Chemical and physical soil analyses were conducted using standard laboratory methods (Sandoval and Power 1978).

Study 3

Spoil samples were collected from three different types of reclamation areas at the McKinley Mine and on three unmined areas. Soil was sampled on unmined areas in open grassland, under fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.) and under one-seed Juniper (*Juniperus monosperma* (Engelm.) Sarg.). Reclaimed sample areas were: spoil amended with bark, spoil amended with straw 1 and 2 years previously, and spoil "topsoiled" 1 and 2 years previously with soil taken from a nearby borrow area. Samples were transported to the laboratory in an insulated container. Samples were thoroughly mixed, and 500-700 cm^3 were placed in a modified Tullgren extractor. Microarthropods were collected in water, counted and identified.

Results and Discussion

Study 1

An average of 1,850 termites (*R. tibialis*) was collected on each of the 100-m^2 grids, which converts to an estimate of 185,000 termites per hectare (92,500 foragers per acre). In other studies, it has been observed that bait rolls greatly underestimate subterranean termite populations, because only a fraction of the physiologically active termites feed at the surface at any one time. These data, however, indicate that *R. tibialis* is an important component of pinyon-juniper and sagebrush communities in northwestern New Mexico.

Study 2

This preliminary study with *R. tibialis* on strip mine spoil with only paper bait rolls as an energy source is indicative of the ability of these organisms to cause rapid changes in chemical and physical properties of spoil material. For termites to utilize the energy of a relatively pure form of cellulose (paper, for example), they need a variety of inorganic salts for their own metabolism and to maintain the activity of their symbiotic microflora (Breznak et al., 1973). To obtain these salts in nature, termites ingest quantities of soil, pass it through their digestive system, and use this material mixed with indigestible food and wastes (fecal material) to form a paste, termed "carton", which sets on drying. This carton is used extensively to line their galleries (Lee and Wood 1971). This activity had a marked effect on the chemical as well as the physical properties of the spoil used in this study (table 1). Some ions were released from the insoluble state and others bound into soluble salts after passage through the termite gut, e.g. soluble Na^+ and $SO_4^=$ were reduced while HCO_3^- and $PO_4^=$ increased. Unfortunately, total nitrogen and total carbon could not be obtained on these samples. In a separate study in southern New Mexico, we found that soil from a profile containing termite gallery carton contained 2,460 ppm total N in comparison to 480 ppm total N in non-carton soil.[3]

There were marked differences in texture and appearance of the untreated spoil when

[3] *Ettershank and Whitford, unpublished data.*

Table 1.—Estimated chemical and physical means of mine spoil from the McKinley Mine, treated with termites and paper bait rolls as an energy source

	EC mmhos	Saturated paste pH	Na^+	Ca++	Mg++	K^+
			meq/l			
Spoil	3.37	7.48	47.7	0.97	0.52	0.59
Spoil/termites	1.66	7.63	16.6	3.00	0.72	0.47
	$SO_4^=$	CO_3	HCO_3^-	Cl^-	$PO_4^=$	NO_3^-
	meq/l				ppm	
Spoil	46.5	0	0.2	0.06	0.02	3.9
Spoil/termites	17.2	0	2.6	0.59	0.26	0.55
	% Organic matter	% Saturated		% Sand	% Silt	% Clay
Spoil	3.96	71.1		35.2	26.0	38.8
Spoil/termites	2.13	23.2		52.2	20.5	27.3

compared to termite worked spoil (fig. 1). The termite amended spoil (lower part fig. 1) was more friable and uniform and was observed to wet evenly. The unworked spoil (upper part fig. 1) was lumpy and wet unevenly; indeed, this material had to stand in water to become saturated. The termite activity, resulting in the formation of carton, also had beneficial effects on the physical characteristics of the spoil by breaking up the large chunks and mechanically mixing the material, producing a sandy-clay-loam texture (table 1, fig. 1). It will be seen from the mechanical analysis in table 1 that in the spoil with termites, the percent of sand increases at the expense of silt and clay. This apparent anomaly is a result of the termites selectively removing silt and clay to build galleries in the paper bait roll. In the field, this activity would enhance porosity, percolation, and aeration of the substrate.

Study 3

Straw amended spoil had a complex micro-arthropod fauna on both the 1- and 2-year-old areas (table 2).

There were no differences in density of the soil microarthropod fauna under juniper and in pine bark amended spoil (table 2). The presence of soil microarthropods is indicative of a mature or maturing soil ecosystem. Santos et al. (1978) found that Mesostigmatid mites (which were found on both undisturbed and reclaimed areas) are typical of arid soils. In detailed studies of litter bags on the Jornada site, near Las Cruces, N. Mex., the authors consistently found that high population densities of mites are associated with high activity of soil micro-organisms (fungi and bacteria). Some of the soil Prostigmatid mites are fungivores and/or nematode predators, and greatly affect rates of organic matter breakdown and mineralization.

Samples from spoil covered with a 0- to 5-cm layer of borrow soil but with no mulch had no microarthropod fauna (table 2). The absence of soil microarthropods on spoils top-dressed with borrow soil suggests that this "topsoiling" without the addition of organic mulch will not restore the soil microarthropods quickly. Additional studies are underway which will include gathering data on fungi and bacteria. Raw mine spoil is amended with organic matter and inoculated with soil microarthropods to determine if the population will rapidly build up and yield a soil that will sustain a community of desirable plant species.

Future Work

Although these are preliminary studies, they suggest some procedures for re-establishing soils on strip mine spoils more rapidly and possibly at a lower cost than at present. It is evident that soil arthropods, especially subterranean termites in an arid region, can produce marked and beneficial changes in the physical and chemical characteristics of mine spoil material when the termites are provided with a suitable source of energy (paper, wood, straw, etc.). Techniques for establishing termite colonies on coal strip mine spoils are under study.

Table 2.—Average numbers and taxa of microarthropods extracted from 500-700 cm^3 of soil from disturbed and undisturbed areas at the Pittsburg and Midway McKinley Mine

Taxon	Open	Under *Atriplex canescens*	Under *Juniperus monosperma*	Spoil with bark	Spoil with straw 1 year	Spoil with straw 2 years	Spoil with borrow soil 1 year	Spoil with borrow soil 2 years
Cryptostigmata Oribatei	11	23	22					
Prostigmata Nanorchestidae	0	0	0	44	5	7	0	0
Other Prostigmata	18	36	76	2	7	8	0	0
Mesostigmata	0	0	0	0	0	17	0	0
Astigmata Acaridae	0	0	0	0	30	20	0	0
Other Mites	21	51	76	113	12	18	0	0
Collembola	2	0	0	20	0	6	0	0
Insects	2	4	10	6	4	0	1	0
Total	54	114	184	185	58	76	1	0

A

B

Figure 1.—Mine spoil material from McKinley Mine which had been subjected to termite activity: (A) mine spoil not worked by termites compared with (B) mine spoil that had termites feeding on paper bait rolls. Note the friable, granualr appearance of the spoil containing termite carton in contrast to the untreated spoil. (15 X magnification)

Literature Cited

Breznak, J. A., W. J. Brill, J. W. Mertins, and H. C. Coppel. 1973. Nitrogen fixation in termites. Nature 244:577-579.

Lee, K. E., and T. G. Wood. 1971. Termites and soil. Academic Press, N. Y. 25 p.

Sandoval, F. M. and J. F. Power. 1978. Laboratory methods recommended for chemical analysis of mined-land spoils and overburden in Western United States. U.S. Dep. Agric., Agric. Handb. 525. 31 p.

Santos, P. F., E. DePree, and W. G. Whitford. 1978. Spatial distribution of litter and microarthropods in a Chihuahuan desert ecosystem. J. Arid Environ. 1:41-48.

Witkamp, M. 1971. Soils as components of ecosystems. *In* Annual Review of Ecology and Systematics. Johnson, R. F., ed. 2:85-110. Annu. Rev., Inc. Palo Alto, Calif. 510 p.

SURFACE ENVIRONMENT & MINING
SEAM
PROGRAM

ecember 1978

RESEARCH NOTE RM- 362

REST SERVICE
. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

UNIVERSITY LIBRARY
JUN 11 197
TECH.

Abert Squirrel Use of Ponderosa Pine as Feed Trees

Peter F. Ffolliott and David R. Patton[1]

The number of twigs found under ponderosa pine (*Pinus ponderosa*) were counted to determine Abert squirrel (*Sciurus aberti*) feed tree patterns and preferences on five Beaver Creek watersheds in Arizona. After 4 years of study, 56% of the feed trees were used 1 year in 4; 29% were used 2 years in 4; 13% were used 3 years in 4; and 2% were used in all 4 years. No pattern of feed tree selection within or among years studied was found; however, Abert squirrels preferred trees 14 to 22 inches in diameter, located in sites having 100 to 150 square feet basal area per acre. Silvicultural treatments had little effect upon feed tree selection.

Keywords: Abert Squirrel, ponderosa pine

Some foresters consider the Abert squirrel a destructive animal, because it commonly feeds on twigs and cones of ponderosa pine trees. However, the amount of damage is debatable (Coughlin 1938, Pearson 1950, Squillace 1953). Larson and Schubert (1970) were the first to document long-term twig and cone clipping of ponderosa pine by the Abert squirrel. They believed that high squirrel populations could preclude an adequate seed supply except in "bumper crop" years. Results from their north-central Arizona study indicated a 20% loss in cone production over a 10-year period.

There is some indication that Abert squirrels prefer particular trees for feeding (Farentinos 1972, Goldman 1928, Hall 1967, Keith 1965, Pearson 1950). It is not known why there is a choice, as those trees used do not appear different from trees which are not used. Keith (1965) suggested a qualitative difference, but neither Hall[2] nor Pederson et al. (1976) could document this difference in chemical analyses.

[1]*Ffolliott, is Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Patton is Principal Wildlife Biologist, located at the Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Laboratory at Tempe, in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Hall, J. G. 1967. The Kaibab squirrel in Grand Canyon National Park. A seven seasons summary 1960-1966. U.S. Dep. Inter., Natl. Park Serv., Grand Canyon, Ariz. Unpubl. rep. 54 p.*

Although heavy use of twigs and cones may be harmful to a given tree, there is recent evidence to indicate that feeding activities may be beneficial to a forest ecosystem through a nutrient transfer process. Working in a ponderosa pine forest in north-central Arizona, Skinner (1976) found that as much as 60 kg/ha of nitrogen could be transferred annually from twigs, cone parts, needles, and bark to the soil as a result of Abert squirrel feeding.

Because of conflicting views on the damage or use of ponderosa pine by Abert squirrels, more information is needed to document the feeding activity and how it changes over time. To this end, the USDA Forest Service and the University of Arizona initiated a cooperative study to determine: (1) if the same trees are selected for twig clipping from year to year; and (2) if the level of twig clipping activity varies from year to year in the same tree. Also, it was determined whether certain tree sizes are consistently selected for twig clipping, and if these trees are associated with specific forest density conditions.

Methods

All field data were collected on five watersheds (8, 10, 13, 14, and 17) within the Beaver Creek Watershed located on the Coconino National Forest in north-central Arizona (Brown et al. 1974). The area sampled totaled approximately 1,920 ha.

Twigs clipped by feeding squirrels were counted under the crowns of 1,390 permanently identified trees selected with a basal area factor (BAF) of 25 at 900 randomly located sample points. Both needled and peeled twigs were counted. Peeled twigs are definitely a characteristic of Abert squirrel feeding, while needled twigs are common to the feeding activities of both Abert and red squirrels (*Tamiasciurus hudsonicus mogollonensis*) (Rasmussen et al. 1975).

Twigs were counted each spring during 4 consecutive years (1973 through 1976), and feed trees were classified into one of four groups: none (0), light use (less than 10), moderate use (10-50), and heavy use (more than 50). Feed trees were defined as trees that had clipped twigs under their crowns. Cone parts were not included in the analysis.

Results

While different silvicultural treatments (thinning-shelterwood, patch cutting-thinning, group selection, irregular strip-shelterwood, and severe thinning) had been imposed on the five watersheds sampled (Brown et al. 1974), there were no differences in the field data collected during the study period. Therefore, all of the field data were grouped for analysis.

Of the 1,390 trees (approximately 18 cm in diameter and larger) examined, 65% were used as feed trees at least once during the 4-year period. Fifty-six percent of the feed trees were used 1 year in 4; 29% were used 2 years in 4; 13% were used 3 years in 4; and only 2 were used in all 4 years.

Under the 508 feed trees used 1 year in 4, fewer than 10 twigs were found beneath 80%, 10 to 50 twigs were found beneath 16%, and more than 50 twigs were found beneath 4%. Similar distributions in yearly twig counts were noted under feed trees used 2, 3, and 4 years.

There was no pattern to the selection of feed trees exhibiting light use within or among the years studied. Furthermore, while some trees were visited in consecutive years, other trees were only utilized once.

In contrast to this, a pattern suggesting a "rotation of use" seemed evident with trees exclusively characterized by moderate or heavy use. There, Abert squirrels did not usually return to the same tree each year, but instead alternated years of twig clipping with 2 or 3 years of no use. This latter observation is contrary to the use pattern described by Larson and Schubert (1970), who reported repeated twig clipping of the same tree year after year.

Infrequently, feed trees were subjected to moderate or heavy use in consecutive years. Trees were severely damaged only when this occurred. However, no tree mortality directly attributable to Abert squirrel feeding was observed during the study period.

Most of the twig clipping followed the pattern described by Pearson (1950), with Abert squirrels preferring the upper portions of tree crowns, especially terminals and upper laterals. In particular, loss of upper crown foliage was observed in the few trees under which large numbers of twigs (more than 50) were found in 2 or more consecutive years (fig. 1).

Figure 1. Loss of foliage in ponderosa pine feed trees under which more than 50 twigs were found in (A) 2 consecutive years, and (B) 3 consecutive years.

Identifying feed trees by size class showed that, while Abert squirrels fed in trees 8 to 34 inches in diameter, they selected 14 - to 22-inch trees, as reported earlier (Patton and Green 1970, Ffolliott and Patton 1975). The preferred size classes were similar on all study areas, suggesting that the silvicultural treatments imposed had little effect on feed tree selection.

In classifying feed tree sites in terms of surrounding forest density, approximately 85% of the sites examined were characterized by basal area levels between 75 and 175 square feet per acre, again independent of treatment. The highest percentage of sites were in the 100- to 150-square-foot range. Generally, tree sizes corresponding with those preferred by Abert squirrels as feed trees comprised most of the basal area.

Conclusions

This study indicates that Abert squirrels cause minimal damage in ponderosa pine. However, by understanding interactions between the squirrel and its selection of feed trees over time, a land manager may suggest forest management activities that can enhance the opportunities of feed tree occurrence (i.e., retaining preferred size classes and density levels).

Literature Cited

Brown, Harry E., Malchus B. Baker, Jr., James J. Rogers, Warren P. Clary, J. L. Kovner, Frederic R. Larson, Charles C. Avery, and Ralph C. Campbell. 1974. Opportunities for increasing water yields and other multiple use values on ponderosa pine forest lands. USDA For. Serv. Res. Pap. RM-129, 39 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Coughlin, L. E. 1938. The case against the tuft-eared squirrel. U. S. For. Serv. Rocky Mt. Reg. Bull. 21:(4)10-12.

Farentinos, R. C. 1972. Observations on the ecology of the tassel-eared squirrel. J. Wildl. Manage. 36:1234-1239.

Ffolliott, P. F., and D. R. Patton. 1975. Production-rating functions for Abert squirrels in southwestern ponderosa pine. The Wildl. Soc. Bull. 3:162-165.

Goldman, E. A. 1928. The Kaibab or white-tailed squirrel. J. Mammal. 9:127-129.

Keith, J. O. 1965. The Abert squirrel and its dependence on ponderosa pine. Ecology 46: 150-163.

Larson, M. M., and Gilbert H. Schubert. 1970. Cone crops of ponderosa pine in central Arizona, including the influence of Abert squirrels. USDA For. Serv. Res. Pap. RM-58, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Patton, David R., and Win Green. 1970. Abert's squirrels prefer mature ponderosa pine. US DA For. Serv. Res. Note R M-169, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pearson, Gilbert A. 1950. Management of ponderosa pine in the Southwest as developed by research and experimental practices. U. S. Dep. Agric. Monogr. 6, 218 p.

Pederson, Jordan C., Robert N. Hasenyager, and Albert W. Heggen. 1976. Habitat requirements of the Abert squirrel (*Sciurus aberti navajo*) on the Monticello District, Manti-Lasal National Forest of Utah. Pub. No. 76-9, 108 p. State of Utah, Dep. Nat. Resour., Div. Wildl. Serv.

Rasmussen, D. Irwin, David E. Brown, and Dale E. Jones. 1975. Use of ponderosa pine by tassel-eared squirrels and a key to determine evidence of their use from that of red squirrels and porcupines. Ariz. Game and Fish Dep., Wildl. Dig. 10, 12 p.

Skinner, Thomas H. 1976. Contribution of Abert squirrel to nutrient transfer through litterfall in ponderosa pine ecosystem. M. S. Thesis. Univ. Ariz., Tucson. 77 p.

Squillace, A. E. 1953. Effects of squirrels on the supply of ponderosa pine seed. USDA For. Serv., North. Rocky Mt. For. and Range Exp. Stn. Res. Note 131, 4 p., Missoula, Mont.

Agriculture — CSU, Fort Collins

ary 1979

RESEARCH NOTE RM-363

REST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Roots of Lodgepole Pine Seedlings Reach Depth of Only 3 to 4 Inches Their First Season

CLEMSON UNIVERSITY LIBRARY
JUN 1979
SCI., TECH. & AGR. DIV.

Daniel L. Noble[1]

First-season lodgepole pine seedlings only had an average rooting depth of 3.8 inches (9.6 cm), 26 branch roots, and a total root length of 9.8 inches (24.9 cm). Seedlings were field-grown in 1977 on scarified-unshaded seedbeds in the central Rocky Mountains, Colorado.

Keywords: Root development, seedling growth, *Pinus contorta*.

Root growth is important for survival of lodgepole pine seedlings (*Pinus contorta*), especially during the first growing season. Deeper root penetration will increase the chances of seedlings surviving drought, frost-heaving, and erosion.

Roots of young lodgepole pine grow slowly; seedlings often form a taproot (Bates 1930, Fowells 1965). Lotan (1964) reported that most mortality of lodgepole pine seedlings in southwestern Montana and eastern Idaho occurred early in the season and was caused by drought. Further, while root growth was not studied in detail, excavations of a few seedlings showed root growth of only 5 to 6 inches on trenched and scalped seedbeds (Lotan 1964). Sims (1964) reported an average root length of 4.7 inches (120 mm) and 23 branch roots for first-year jack pine (*Pinus banksiana* Lamb.) which hydridizes with lodgepole pine.

No information was found on root growth for first-season lodgepole pine seedlings in the central and southern Rocky Mountains. This study was made to provide estimates of: (1) rooting depth—main root in its unextended position following washing (fig. 1); (2) number and length of unextended branch roots; and (3) total root length—rooting depth plus branch roots—for 16-week-old field-grown lodgepole pine seedlings in the central Rocky Mountains.

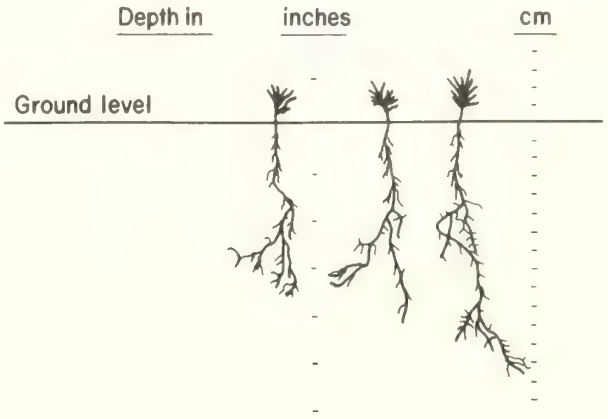


Figure 1.—Rooting depths of 16-week-old lodgepole pine seedlings.

[1]*Ecologist, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Rapid City in cooperation with South Dakota School of Mines and Technology; Station's central headquarters maintained in Fort Collins, in cooperation with Colorado State University.*

Study Area

Seedlings were grown on the Fraser Experimental Forest, Colorado, in what appeared to be a natural, nearly level opening of about 2 acres (0.8 ha) at an elevation of 8,900 feet (2,713 m). Dominant vegetation surrounding the opening is second growth, 60-year-old lodgepole pine with an understory dominated by whortleberry (*Vaccinium* spp.) and kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng). Vegetation in the opening is a dense stand of grasses and forbs dominated by Idaho fescue (*Festuca idahoensis* Elmer), perennial lupines (*Lupinus* spp.), and strawberry (*Fragaria* spp.).

The climate of the area is typical of the subalpine zone of the western slope of the Front Range. Temperatures range from -40° to 90° F (-40° to 32° C) and precipitation from 18 to 34 inches (46 to 86 cm) annually. Haeffner (1971) provided a climatological summary of the experimental area.

Temperatures and precipitation during the summer—June through September—were important to this study. Average temperatures over a 31-year period (1940-1971) were: maximum 69.5° F (21° C), minimum 33° F (0.6° C, and mean 50° F (10° C). Average summer precipitation was 7.6 inches (19.3 cm), with a range from 5.7 to 9.5 inches (14.5 to 24.1 cm). Temperature and precipitation data were measured at the headquarters station, approximately 1 mile (1.64 km) from the study area and less than 150 feet (45.7 m) higher in elevation than the study site.

The soil is classified as Tabernash loam and mapped as Tabernash loam and Mine gravelly loam. It developed from material weathered from mixed gneisses and schists, and was deposited over the study area from glacial outwash (Retzer 1962). Laboratory analysis, from mineral surface to 8 inches (20.3 cm) depth, showed approximately 30%, 47%, and 23% sand, silt, and clay, respectively. Moisture contents at tensions of minus 1/3 and 15 bars were approximately 20% and 10% respectively.

Methods and Materials

Temperatures and precipitation were recorded on the study area during the summer of 1977 with a recording hygrothermograph and dial maximum-minimum thermometer in a standard U.S. Weather Bureau shelter. A standard 8-inch (2.03-cm) rain gage, without funnel or tube, was weighed weekly to measure precipitation.

In late September 1976, three 6-foot-square (1.8-square) seedbeds, each 20 feet (6.1 m) apart were hand scarified to mineral soil (fig. 2).

Figure 2.—Seedbed scarified to mineral soil. Plastic tags marked seedling locations.

Table 1.—Measurement of first-season lodgepole pine seedlings from the central Colorado Rockies

Measurement	Mean	Maximum	Minimum	Standard error
Number of branch roots	26.1	51	9	1.83
Root/shoot ratio	3.9	5.9	1.9	0.16
		- - *in* - -		
Root depth	3.8	5.3	2.5	0.10
Total root length	9.8	16.8	4.4	0.44
Seedling height	1.0	1.5	0.6	0.03

Immediately following scarification, approximately 1,000 seeds (local seed source with 65% laboratory germination) were sown on the surface of each seedbed.

Seedlings that germinated between June 4 and 10, 1977 were measured when they were 16 weeks old. Seedlings were carefully excavated with a shovel and trowel and the soil washed from the roots using a gentle rinsing action with a coarse soil-screen and a water-filled barrel.

Results

A total of 48 seedlings, 16 from each seedbed, were measured. Analyses showed no significant differences in rooting depth, number of branch roots, total root length, seedling height or root/shoot ratios among groups of seedlings from the three seedbeds. Therefore, seedling growth measurements were combined to calculate means, ranges, and standard errors (table 1).

Average temperatures were near normal during the 1977 growing season; with a 70.7° F (22° C) maximum; 36.5° F (2.5° C) minimum, and 53.6° F (12° C) mean. Precipitation, while poorly distributed, was 1.2 inches (3.0 cm) above normal.

Discussion and Conclusion

Data collected from one growing season indicated that 16-week-old lodgepole pine seedlings develop a shallow root system under field conditions. Rooting depth was approximately 3.8 inches (9.6 cm), with about 26 branch roots, and a total root growth of 9.8 inches (24.9 cm).

Lodgepole pine seedlings extend their roots to about the same depth during the first growing season as seedlings of Engelmann spruce (*Picea engelmannii* Parry), a common associate on the Fraser Experimental Forest (Noble 1973). However, lodgepole pine seedlings develop more than twice as many branch roots and almost twice the root length. The greater root development of intolerant lodgepole pine, compared to spruce, may partly explain why lodgepole pine becomes established on drier sites than Engelmann spruce does.

Nevertheless, the lack of a deeper root system for lodgepole pine seedlings is a major factor contributing to mortality on both mineral soil and undisturbed areas. Under drought conditions, first-summer root growth may not be adequate to keep up with available soil moisture. Further, first-year seedlings with shallow root systems are probably more susceptible to frost-heaving, especially on mineral soil seedbeds.

Literature Cited

Bates, C.G. 1930. The production, extraction, and germination of lodgepole pine seed. U.S. Dep. Agric. Tech. Bull. 191, 92 p.

Fowells, H. A. 1965. Silvics of forest trees of the United States. U.S. Dep. Agric., Agric. Handb. 271, 762 p.

Haeffner, Arden, D. 1971. Daily temperatures and precipitation for subalpine forest, central Colorado. USDA For. Serv. Res. Pap. RM-80, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Lotan, James E. 1964. Initial germination and survival of lodgepole pine on prepared seedbeds. USDA For. Serv. Res. Note INT-29, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Noble, Daniel. L. 1973. Engelmann spruce seedling roots reach depth of 3 to 4 inches their first season. USDA For. Serv. Res. Note RM-241, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Retzer, J. L. 1962. Soil survey of Fraser alpine area, Colorado. Soil Surv. Ser. 1956, No. 20, 47 p. U.S. Dep. Agric. Exp. Stn., U.S. Gov. Print Off.

Sims, H. P. 1964. Root development of jack pine seedlings on burned-over dry sites in south-Eastern Manitoba. Can. Dep. For. Publ. No. 1061, 15 p.

ary 1979

RESEARCH NOTE RM-364

REST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Food Habits of Coyotes in a Semidesert Grass-Shrub Habitat

CLEMSON UNIVERSITY LIBRARY
JUN 11 1979
SCI. TECH. & AGR. DIV.

Henry L. Short[1]

Coyotes (*Canis latrans*) feeding in a semidesert grass-shrub habitat consume a variety of foodstuffs throughout the year. The relative incidence of several plant and animal items in coyote scats did not seem to vary throughout the year. The incidence of other items, like pocketmice (*Perognathus* spp.) in late winter and spring, bird eggs in early summer, and the fruits of prickly pear (*Opuntia engelmannii*) and mesquite (*Prosopis juliflora*) in late summer, varied in an interpretable manner between months.

Keywords: Coyotes, *Canis latrans*, foot habits, scat analysis, Sonoran Desert.

Predators in cold climates frequently rely on a single prey species as their major food source (Emlen 1973) while predators in warmer climates consume a variety of foods (Murie 1951, Sperry 1941, Truett and Day 1966). The complex food habits of coyotes (*Canis latrans*) in a semidesert grass-shrub habitat in the Southwest is described in this study conducted on the Santa Rita Experimental Range (SRER), Pima County, Arizona.

Study Area

The 20,000-ha Santa Rita Experimental Range extends northward toward Tucson from the foothills of the Santa Rita Mountains. Average annual rainfall varies from about 25 cm at 885 m to about 50 cm at 1310 m (Martin and Reynolds 1973). Velvet mesquite (*Prosopis juliflora*), cholla cactus (*Opuntia* spp.) and prickly pear (*O. engelmannii*) are abundant throughout the range. Other shrubs locally common include burroweed (*Haplopappus tenuisectus*), acacias (*Acacia* spp.), mimosa (*Mimosa* spp.), false mesquite (*Calliandra eriophylla*), and ocotillo (*Fouquieria splendens*). Several threeawns (*Aristida* spp.), gramas (*Bouteloua* spp.), and other grasses are present and generally increase in abundance as elevation and precipitation increase.

Common mammals on the Santa Rita Experimental Range include the black-tailed jack rabbit (*Lepus californicus*), antelope jack rabbit (*L. alleni*), desert cottontail (*Sylvilagus audubonii*), Harris' antelope squirrel (*Ammospermophilus harrisii*), round-tailed ground squirrel (*Spermophilus tereticaudus*), Botta's pocket gopher (*Thomomys bottae*), desert pocket mouse (*Perognathus penicillatus*), Ord's kangaroo rat (*Dipodomys ordii*), Merriam's

[1]*Formerly Principal Research Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service. Central headquarters located at Fort Collins, Colo., in cooperation with Colorado State University. Author was stationed at Forest Hydrology Laboratory, Tempe, Ariz., in cooperation with Arizona State University. Author is Terrestrial Ecologist, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colo.*

kangaroo rat (*D. merriami*), western harvest mouse (*Reithrodontomys megalotis*), deer mouse (*Peromyscus maniculatus*), cactus mouse (*P. eremicus*), southern grasshopper mouse (*Onychomys torridus*), white-throated woodrat (*Neotoma albigula*), gray fox (*Urocyon cinereoargenteus*), ringtail (*Bassariscus astutus*), striped skunk (*Mephitis mephitis*), collared peccary (*Dicotyles tajacu*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*O. hemionus*).

Common birds include Gambel's quail (*Lophortyx gambelii*), road-runner (*Geococcyx californianus*), lesser nighthawk (*Chordeiles acutipennis*), ladder-backed woodpecker (*Picoides scalaris*), black phoebe (*Sayornis nigricans*), Say's phoebe (*Sayornis saya*), ash-throated flycatcher (*Myiarchus cinerascens*), cactus wren (*Campylorhynchus brunneicapillum*), rock wren (*Salpinctes obsoletus*), mockingbird (*Mimus polyglottos*), phainopepla (*Phainopepla nitens*), yellow-rumped warbler (*Dendroica coronata*), cardinal (*Cardinalis cardinalis*), house finch (*Carpodacus mexicanus*), brown towhee (*Pipilo fuscus*), white-crowned sparrow (*Zonotrichia leucophrys*), and black-throated sparrow (*Amphispiza bilineata*) (Martin and Reynolds 1973).

Common reptiles include Clark's spiny lizard (*Sceloporus clarki*), eastern fence lizard (*S. undulatus*), short-horned lizard (*Phrynosoma douglassi*), gila monster (*Heloderma suspectum*), southern whiptail (*Cnemidophorus tigris*), Sonora whipsnake (*Masticophis bilineatus*), striped whipsnake (*M. taeniatus*), gopher snake (*Pituophis melanoleucus*), black-tailed rattlesnake (*Crotalus molossus*), and western rattlesnake (*C. viridis*) (Martin and Reynolds 1973).

Food sources potentially available to coyotes on or near the Santa Rita Experimental Range also include a large cattle feedlot operation and an extensive pecan orchard along the bottomlands of the Santa Cruz River. Both the feedlot and the orchard are adjacent to the western edge of the SRER.

Methods

Coyote scats were collected from four standardized areas on the SRER. Each area included a fenced apron around a water source (stock tank, trick tank, or gallinaceous guzzler) and 5 to 7 km of little used dirt roads. The total area searched for scats in each of the four collection sites ranged between 2.2 and 2.3 ha. The four permanent sampling areas were established and cleared of carnivore scats during mid-December 1974. Scats were collected about mid-month during each calendar month of 1975.

Individual coyote scats were placed in separate plastic bags which were labeled as to area and date of collection and were stored dry in a freezer. Each scat was later analyzed after being washed until soft enough to separate the contents. Items found in the scats, such as bones, teeth, feathers, hair, and seeds, were identified by comparison with known reference materials. Each coyote scat was treated as an individual observation and all the identifiable contents were recorded. Total number of scats collected, the total number of mammalian or plant remains per scat, and the incidence of particular food items in the scats collected each month are listed in table 1.

Results

A total of 960 coyote scats was collected during 1975 and subsequently analyzed from the four collection areas. Each coyote scat contained the remains of about 3.2 different food items. The number of different species of mammals found in each scat seemed less from August through October than during the other months, probably because of the increased consumption of fruits of mesquite and cactus during summer.

The incidence of the remains of jackrabbits, desert cottontails, kangaroo rats, mice, and woodrats in coyote scats did not seem to vary throughout the year. Pocket mice seemed to be consumed at relatively high rates during winter and early spring. Young pocket mice apparently forage above ground in early spring and are especially vulnerable to predation. Remains of Harris' antelope squirrels were more common in coyote scats collected during March, the month when young squirrels come above ground, than in scats from other months.

Hairs from the collared peccary and mule and white-tailed deer were present in a consistently small proportion of the collected coyote scats throughout the year. There was no evidence that fawns comprised a major food item for coyotes during July and August when partui-

Table 1. Remnants of food items identified in coyote scats from a semidesert grass-shrub habitat throughout the year.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
No. scats per month	118	103	132	117	111	45	12	42	68	84	66	62
No. different items/scat	3.65	2.84	2.92	3.25	3.41	3.67	3.67	3.05	1.81	2.96	3.29	3.71
No. different plant items/scat	1.97	1.34	1.23	1.53	1.52	1.64	1.42	2.05	1.25	1.88	1.89	1.90
No. different mammal spp./scat	1.24	1.27	1.48	1.36	1.32	1.27	1.83	0.64	0.40	0.64	1.04	1.13
Incidence of Food Items[1]												
Lepus spp.	3	7	3	4	2	0	3	3	0	12	12	4
Sylvilagus audubonii	7	12	15	8	15	14	6	3	5	14	14	14
Total Leporidae	22	35	27	27	28	20	9	6	6	26	30	18
Perognathus spp.	21	12	19	26	18	15	6	3	1	1	3	0
Dipodomys spp.	11	4	7	5	0	0	6	3	12	4	2	0
Peromyscus spp.	1	4	5	10	3	2	6	1	0	0	1	0
Neotoma spp.	15	6	10	12	7	12	16	9	18	6	10	17
Ammospermophilus spp.	2	0	11	2	1	0	0	0	0	4	1	0
Total rodents	69	40	75	74	66	52	53	27	31	30	41	40
Dicotyles tajacu	2	11	2	3	1	0	6	0	0	1	2	2
Odocoileus spp.	4	14	14	7	10	19	13	20	0	0	5	17
Cattle	17	15	23	17	11	7	0	0	1	5	24	26
Total reptiles	5	4	2	5	4	6	0	12	0	2	0	3
Total insects	12	4	1	17	10	17	6	10	7	42	7	23
Total birds	15	8	11	13	16	18	9	9	2	13	18	24
Egg shells	0	1	1	1	26	14	3	6	0	1	0	0
Opuntia engelmannii fruit	2	0	4	5	0	2	0	43	99	66	18	4
Total cactus fruit	5	1	7	8	1	2	0	50	99	66	25	12
Prosopis juliflora (fruit)	9	2	5	5	1	2	3	65	3	53	16	16
Prosopis juliflora (leaves)	42	40	38	39	16	43	19	14	1	4	38	35
Grass	55	51	60	48	56	35	25	27	24	49	64	68
Pecans	14	8	5	11	7	17	3	0	0	0	1	10
Misc. vegetation	81	51	29	57	60	67	50	33	3	13	41	52
Misc. non-food items	6	1	0	3	3	2	0	2	0	0	2	8

[1]*Percent of coyote scats collected during each month that contain particular food items.*

tion was occurring or that crippled collared peccary were consumed at high levels during the hunting season in February. Carrion from the nearby cattle feedlot operation seemed to be a major food item for coyotes during both autumn and winter. Feedlot carrion was not found in scats collected during the summer. Perhaps this difference was due to seasonal changes in feedlot operation, changes in the behavioral patterns of coyotes feeding at the feedlots so that they no longer frequented the collection areas, or seasonal changes in coyote food habits.

The incidence of remains of reptiles, insects, and birds in coyote scats was low and did not seem to vary between months. These food items may not be highly selected by coyotes at any time of the year. A variety of birds, including Gambel's quail, roadrunners, and black-throated sparrows, nest on or near the ground from mid-April through mid-June at the SRER and the incidence of egg shells in coyote scats seemed greater in May and June. The coyote may be efficient at finding and destroying bird nests during the incubation season when the nests are highly vulnerable.

Many species of cacti in the Sonoran Desert bear fruit during the summer and coyotes feed on cactus fruits when they are ripe. Remains of prickly pear fruits were present in most of the coyote scats collected in September and October. One-half of the scats collected during August also contained the remains of prickly pear and other cactus fruits.

Velvet mesquite leaves were less abundant in coyote scats during September and October than during most of the other months. Beans of this spiny deciduous tree are palatable to wildlife and livestock and were apparently consumed at higher rates when ripe during August and October than during other months.

Remnants of grasses were frequently present in the coyote scats. The incidence of grass remains was less during summer months than during the other seasons. Grass may be eaten to provide bulk in the diet and is probably present

in the collected scats out of proportion to its actual value in the coyote's diet. Grass celluloses are of very limited digestibility to simple-stomached animals and consequently grasses eaten may be recovered more or less undigested.

Pecans are available on the ground in the large pecan orchard bordering the SRER during the winter due to storm action and commercial picking operations. Pecans are eaten by coyotes at apparently higher rates during January and remains were found during other months except those of late summer.

A variety of miscellaneous and unidentified vegetation, including fruits, herbage, and woody material, was present in many coyote scats throughout the year. The incidence of these miscellaneous plant materials did not seem to vary between months.

The occasional presence of pieces of leather thongs, plastic, gum wrappers, paper, cloth, and rubber bands in the coyote scats (miscellaneous non-food items in table 1) also emphasize the ubiquitous diet of coyotes on the SRER.

Discussion

Clearly the scat deposition on the four collection sites varied by months. That variability might have been due to one or more of the following seasonal changes in: (1) availability of water, (2) feedlot operations off the SRER which provided carrion as a food source, (3) coyote behavioral activity during summer, (4) numbers of coyotes on the SRER.

The analysis of scats provides some indication of coyote food habits. Obvious difficulties occur, however, in determining the quantity of prey from remains in scats. Are the macerated bones and fur in a single scat from one or several mice? Are the total remains from a single jackrabbit in one or in many scats? How wide an area will the scats containing remains from the same jackrabbit be deposited? Are scats collected from sampling areas 3 to 5 km apart, as in the present study, likely to contain remnants from the same meal?

Scat analyses seem most useful when they are interpreted as indicating only the presence or absence of a particular food item in a systematically collected sample. For example, the data summarized in table 1 obviously indicate that a variety of foodstuffs, including plant materials, are eaten by coyotes on the SRER. Furthermore, some foods (like pocket mice in spring, bird eggs in May and June, and cactus fruits in August through October) seem to occur for interpretable reasons at different frequencies during different months. Additionally, there is no evidence in table 1 to suggest that javelina or deer were actively selected or major seasonal food items for coyotes on the SRER.

It is desirable to know how variations in food habits affect the seasonal deposition of scats on collection areas. Such information could be obtained with suitable feeding studies which would indicate the quantity and types of indigestible remnants from equal-sized meals of animal and vegetative materials of varying digestibility.

Literature Cited

Emlen, J. M. 1973. Ecology: An evolutionary approach. Addison-Wesley Publ. Co., Inc. Philippines. 433 p.

Martin, S.C., and H.G. Reynolds. 1973. The Santa Rita Experimental Range: Your facility for research on semidesert ecosystems. Ariz. Acad. Sci. 8(2):56-67.

Murie, A. 1951. Coyote food habits on a southwestern cattle range. J. Mamm. 32(3):291-295.

Sperry, C.C. 1941. Food habits of the coyote. Fish and Wildl. Serv. USDI, Wildl. Res. Bull. 4. 70 p.

Truett, J.C., and G.I. Day. 1966. Winter food habits of coyotes and bobcats in Arizona. Proc. Fifth Annu. Conf. N. Mex.-Ariz. Sec. Wildl. Soc., Show Low, Ariz. 6 p.

1979

RESEARCH NOTE RM-365

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Key to Small Lepidopterous Larvae in Opening Buds and New Shoots of Douglas-fir and True Firs

V.M. Carolin, Jr.,[1] and Robert E. Stevens[2]

CLEMSON UNIVERSITY
SEP 13 19
SCI., TECH. & AGR. DIV.

Presents a key primarily for field use, emphasizing characters visible with a hand lens. The key centers on associates of the western spruce budworm, *Choristoneura occidentalis* Freeman.

Keywords: Lepidoptera, larvae, *Choristoneura occidentalis*, *Pseudotsuga menziesii*, *Abies* spp.

Field workers involved in western spruce budworm surveys or related activities often need to collect and count small larvae in opening buds and new shoots of host trees. Other foliage-feeding Lepidoptera are also found in the new growth, and it is important to be able to separate and distinguish between the various species.

This key is presented for trial use by survey, control, and research personnel working on western spruce budworm. It is based on notes prepared by the senior author during field studies on the western spruce budworm in Oregon and Washington during the period 1955-1962. We recognize that the key is not inclusive for the entire range of the western spruce budworm, but offer it for interim use while we work to develop a more comprehensive product. Many of the species covered in the key are known to be widely distributed throughout the West; therefore the key is useful to at least some degree in regions other than the Pacific Northwest.

In the 1955-1962 Oregon and Washington studies, larvae of Lepidoptera found in opening buds and expanding shoots were reared in powderboxes on host foliage. Changes in appearance following larval molts were noted, and body length during a stadium was recorded. In most cases, the actual instar is not known. Reared adults were identified by specialists at the U.S. National Museum.

This key enables workers to identify larvae by using a 10X hand lens. The key is restricted to larvae up to about 12 mm long; consequently color is emphasized as a key characteristic. Coloration and markings on the dorsal surface of the last two thoracic segments and the abdominal segments are given special attention, as are coloration and general features of the head, prothoracic shield, anal shield, and sometimes the thoracic legs. Patches of sclerotization (i.e., prespiracular sclerotization on the thorax) are used to a small extent. Many of the body features used in the key are illustrated in figure 1. Variation in color within an instar may at times be greater than indicated in the key. For example, in some localities *Griselda radicana* has a green form in most instars.

Only lepidopterous species are included in this key. Some webspinning sawflies also feed on the new growth of Douglas-fir and true firs. In Oregon, the most common of these are solitary feeders in the genus *Acantholyda*. The black or orange-brown, globose head, wrinkled appearance of the dorsum, long antennae, appendages at the rear, and lack of abdominal prolegs help to identify the group. Also, xyelid sawfly larvae, creamy-white and curled in body shape, occur at times in the center of opening buds of true firs. These are mentioned in the event they are encountered by field workers during bud or shoot examinations.

[1]*Entomologist. Carolin was stationed at the Pacific Northwest Forest and Range Experiment Station, and is now retired.*

[2]*Entomologist. Rocky Mountain Forest and Range Experiment Station with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

We solicit additions to the key and comments about it, and will be actively working to provide a revised version that will give comprehensive coverage throughout the range of the western spruce budworm. Additions to the key should be in the form of authoritatively identified adults reared from larvae, the characteristics of which have been recorded using characters compatible with the key. The junior author will arrange for determinations of specimens not previously identified.

At the end of a trial period of approximately 3 years, we will revise the key and add illustrations that will further help users in picking out diagnostic characters. Please direct questions, additions, and comments to the junior author.

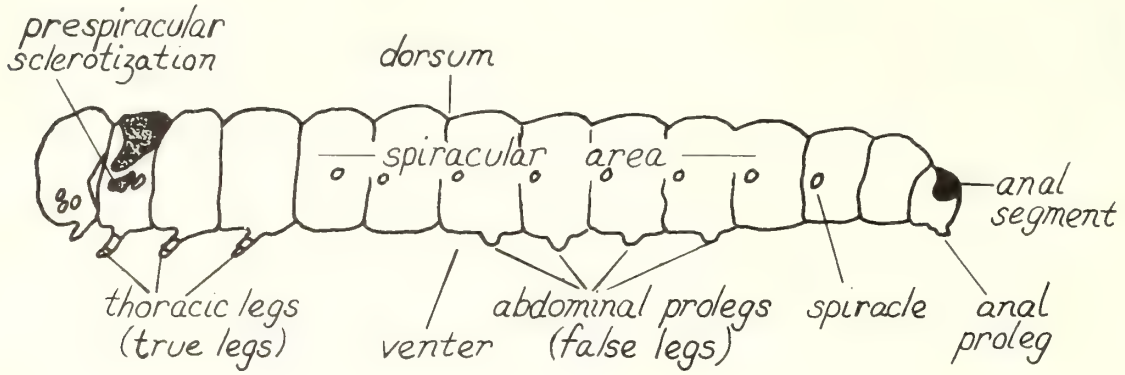
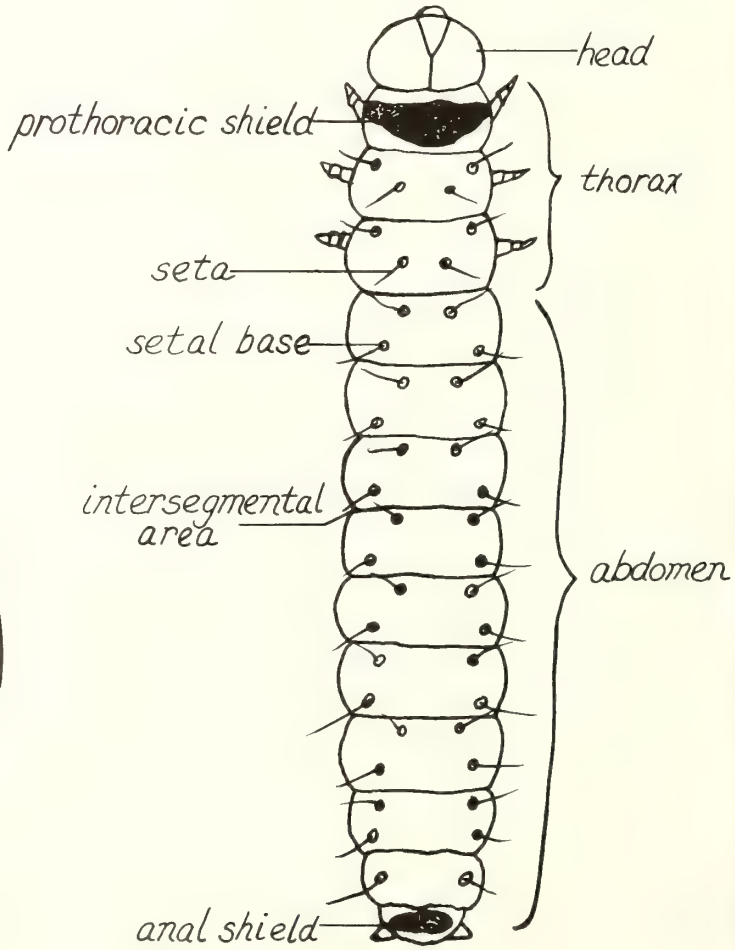
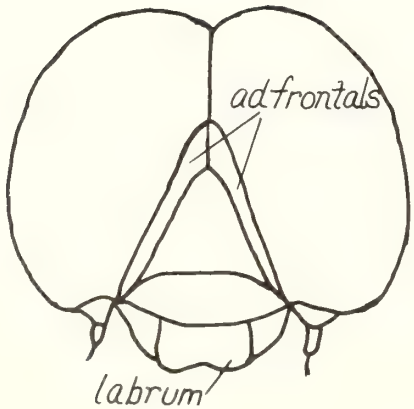


Figure 1- Larval Characters Used in Key





front view of head capsule

Key to Small Lepidopterous Larvae in Opening Buds and New Shoots of Douglas-fir and True firs

A. Larvae with two pairs of false legs, moving with an inching or looping motion based on use of anal prolegs . . . . . Section I. Geometridae

B. Larvae with five pairs of false legs, moving at a constant pace, but often wiggling violently when disturbed . . . . . Section II. Olethreutidae, Tortricidae, Gelechiidae, Pyralidae, and Noctuidae

Section I. Geometridae

1. Dorsum banded dark brown and white on first five abdominal segments, head dark brown to black. Length 4 to 7 mm . . . . . 1st instar *Lambdina fiscellaria lugubrosa*
1. Dorsum either unicolorous, or with longitudinal whitish lines 2
   2. Dorsum light or dark green, with one pair of longitudinal white lines. Length 10 mm and up to 30 mm at maturity. 3
   2. Dorsum yellow to yellow-pinkish-brown, without longitudinal lines. Smaller larvae 5
3. Head pale yellow-brown; dorsum light bluish-green and lines whitish-yellow; spiracular area with a similar line and also a very thin line. Inland forests . . . . . *Enypia* sp.
3. Head green; dorsum apple green to dark green and lines white; spiracular area with a yellow line or stripe. Coastal forests 4
   4. Head green with no markings . . . . . *Melanolophia imitata*
   4. Head green with 10 black dots . . . . . *Nepytia phantasmaria*
5. Head medium to dark brown, dorsum yellowish-brown or pinkish-brown and each segment with four dark dots; spiracular area with three dark brown lines. Body 6 to 15 mm long . . . . . 2nd and 3rd instar *Lambdina fiscellaria lugubrosa*
5. Head light brown; dorsum yellow to brown; no spiracular lines 6
   6. Dorsum bright yellow, becoming pink with three longitudinal purple lines; spiracular area light brown. Body 6 to 10 mm long. Feeds under bud sheath on Douglas-fir . . . . . *Eupithecia annulata*
   6. Dorsum orange-red-brown, with yellow spiracular area and venter; body 10 mm and longer. Open feeder . . . . . *Stenoporpia* sp.

Section II. Olethreutidae, Tortricidae, Gelechiidae, Pyralidae, and Noctuidae

1. Dorsum marked with longitudinal lines; setal bases conspicuous only in *Achytonix* and *Xylomyges* (Noctuidae) 16
1. Dorsum unicolorous; setal bases often a lighter or darker color, causing a slightly spotted or spiny appearance 2
   2. Dorsum yellow-green, bright green, or olive green 14
   2. Dorsum not green, but sometimes with a faint greenish tinge 3
3. Head and prothoracic shield yellow, yellow-brown, light brown, or chestnut brown 12
3. Head dark brown to black; prothoracic shield brown to black; anal shield conspicuous, light brown to black 4
   4. Dorsum orange-brown or olive brown 5
   4. Dorsum yellow, dirty white to light brown, or cinnamon brown 7
5. Prothoracic shield light to medium brown; prespiracular sclerotization light to medium brown; anal shield light brown. Body orange-brown, 5 to 7 mm long (3d instar), or light olive brown, 6 to 10 mm long (early 4th instar) . . . . . *Choristoneura occidentalis*
5. Prothoracic shield, setal areas, and anal shield dark brown to black 6
   6. Dorsum dark olive brown with yellowish-brown in intersegmental areas; setal areas raised; anal shield dark brown, orbicular, body 4 to 5 mm long . . . . . *Achytonix epipaschia*
   6. Dorsum light orange-brown, sometimes with greenish tinge; setal areas not raised; anal shield black, occupying most of anal segment; body 4 to 7 mm long . . . . . *Xylomyges simplex*
7. Dorsum pale yellow to lemon yellow 9
7. Dorsum dirty white to cinnamon brown 8
   8. Dorsum dirty white to light brown; head dark brown and wider than long; prothoracic shield chestnut brown; setal bases dark; anal shield large, dark brown; penultimate abdominal segment with spots of sclerotization; body 6 to 8 mm long . . . . . *Zeiraphera hesperiana*
   8. Dorsum cinnamon brown; head and prothoracic shield black; setal bases pale; anal shield large, pale ivory; body 6 to 12 mm long . . . . . 4th instar *Choristoneura occidentalis*
9. Prothoracic shield and thoracic legs dark brown to black; setal areas inconspicuous 11
9. Prothoracic shield and thoracic legs medium brown; anal shield visible 10
   10. Anal shield dark brown and orbicular, body form slender, 3 to 5 mm long . . . . . *Griselda radicana*
   10. Anal shield outlined on edges by dots of sclerotization; thoracic legs annulated brown and white; setal areas visible; body form moderately stout, body 3 to 5 mm long . . . . . 3rd instar *Choristoneura viridis*
11. Head, prothoracic shield, prespiracular sclerotization, and outside of thoracic legs jet black; anal shield medium brown and oribicular; body 3 to 8 mm long . . . . . *Acleris gloverana*
11. Head black; prothoracic shield and prespiracular sclerotization dark brown; thoracic legs annulated dark brown and white; anal shield represented by a few dots of sclerotization; body 5 to 8 mm long . . . . . 4th instar *Choristoneura viridis*
   12. Head and prothoracic shield chestnut brown, head narrower than body; dorsum pinkish-brown,

yellowish-brown, or cinnamon brown; setal bases prominent; anal shield semicircular, pale chestnut brown and occupying most of segment, body slender, 5 to 7 mm long ..... *Coleotechnites* sp.

12. Head yellow to yellow-brown; dorsum yellow-brown to yellow-green; setal bases and anal shield inconspicuous 13

13. Head as wide as body, wider than long, yellow-brown to pale chestnut brown; anal segment long, yellow, with small shield; body 6 to 8 mm long ..... *Griselda radicana*

13. Head narrower than body, longer than wide; prothoracic shield yellow-brown; anal segment of moderate length, shield inconspicuous, body 4 to 7 mm long ..... *Argyrotaenia dorsalana*

14. Head green with yellow-brown tinging around labrum and adfrontals; thorax, thoracic legs, and abdomen emerald green; body 8 to 12 mm long ..... *Argyrotaenia provana*

14. Head brown to black, body pale yellow-green; body 8 to 10 mm long 15

15. Head, prothoracic shield, and anal shield yellow-brown to pale chestnut brown, with fine black markings in center rear of prothoracic shield; anal shield orbicular ..... *Argyrotaenia dorsalana*

15. Head and thoracic legs dark brown to black; prothoracic shield paler; anal shield inconspicuous ..... *Acleris gloverana*

16. Dorsum reddish-brown or brownish-gray, with 8 to 10 interrupted white longitudinal lines; a large white eyespot around lateral seta on 8th abdominal segment ..... *Dioryctria reniculelloides*

16. Dorsum yellow, greenish-brown, or pale brown; longitudinal lines of various number and color; no eyespot on abdomen 17

17. Dorsum yellow with three orange-brown longitudinal lines; head almost as wide as body and light brown; prothoracic shield light brown; body 8 to 10 mm long ..... *Griselda radicana*

17. Dorsum brownish, greenish-brown, green, or gray-brown 18

18. Dorsum pale brown, reddish-brown, or brownish-gray, with purplish or lavender longitudinal lines; head narrower than body; body form slender ... 21

18. Dorsum green or brownish-green with one or more white longitudinal lines; a yellowish-white stripe in spiracular area; head as wide or almost as wide as body; body form stout 19

19. Dorsum pale olive green with a narrow central white line; head jet black; prothoracic and anal shields dark brown; setal areas dark brown; body 5 to 7 mm long ..... *Achytonix epipaschia*

19. Dorsum variously colored, with three rather broad white longitudinal lines 20

20. Dorsum greenish-brown; head, prothoracic shield, and setal areas black; anal shield dark brown; body 8 to 10 mm long ..... *Xylomyges simplex*

20. Dorsum apple green; head pale yellow-green; prothoracic and anal shields not evident, covered with striping; body 7 to 10 mm long ..... *Achytonix epipaschia*

21. Dorsum pale brown, with 3 to 5 reddish-purple longitudinal lines ..... *Chionodes* spp.

21. Dorsum pale yellow or pale gray with 7 to 9 fine brown-to-lavender lines; often in staminate flowers ..... *Telphusa* sp.

canusa

Canada
United States
Spruce Budworms
Program

il 1979

RESEARCH NOTE RM 366

OREST SERVICE
J.S. DEPARTMENT OF AGRICULTURE

Duration of Snow Accumulation Increases

ERRATA SHEET

for

USDA Forest Service Research Note RM-366

Duration of Snow Accumulation Increases
after Harvesting in Lodgepole Pine in
Wyoming and Colorado

Howard L. Gary

On page 4, the table heading for Table 1 should read:

Table 1.--Average snow water equivalents (mm) in alternate clear-cut and undisturbed forest strips on north and south aspects

improvement in the lodgepole pine forests is clearcutting in small blocks or strips (Leaf 1975). The general prescription is blocks or strips less than 8 tree heights (8 H) in width, protected from wind and spaced at least 5 H apart. In some situations larger cutting units may be justified for disease control.

Studies of snow in lodgepole pine forests generally have shown greater quantities of snow in small openings and clearings and/or in thinned stands than beneath undisturbed

[1]Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

undisturbed forest to the cut areas (Hoover and Leaf 1967). At present it is generally concluded forest openings and forest margins must be considered as a whole in evaluating effects of harvesting on snowpack accumulation (Anderson 1969, Gary 1974).

Dynamic simulation models of the long-term effects of forest and watershed management indicate water yield increases after small patch cuts may persist for at least 50 and perhaps 60 or more years (Alexander and Leaf 1975). However, the long-term effect and time trend of clearcutting in small blocks or strips on snow

yellowish-brown, or cinnamon brown; setal bases prominent; anal shield semicircular, pale chestnut brown and occupying most of segment, body slender, 5 to 7 mm long ..... *Coleotechnites* sp.

12. Head yellow to yellow-brown; dorsum yellow-brown to yellow-green; setal bases and anal shield inconspicuous 13

13. Head as wide as body, wider than long, yellow-brown to pale chestnut brown; anal segment long, yellow, with small shield; body 6 to 8 mm long ..... *Griselda radicana*

13. Head narrower than body, longer than wide; prothoracic shield yellow-brown; anal segment of moderate length, shield inconspicuous, body 4 to 7 mm ..... *Argyrotaenia dorsalana*

16. Dorsum yellow, greenish-brown, or pale brown; longitudinal lines of various number and color; no eyespot on abdomen 17

17. Dorsum yellow with three orange-brown longitudinal lines; head almost as wide as body and light brown; prothoracic shield light brown; body 8 to 10 mm long ..... *Griselda radicana*

17. Dorsum brownish, greenish-brown, green, or gray-brown 18

18. Dorsum pale brown, reddish-brown, or brownish-gray, with purplish or lavender longitudinal lines; head narrower than body; body form slender ... 21

18. Dorsum green or brownish-green with one or more white longitudinal lines; a yellowish-white stripe in spiracular area; head as wide or almost as wide as body; body form stout 19

Canada
United States
Spruce Budworms
Program

Agriculture — CSU, Fort Collins

1979

RESEARCH NOTE RM-366

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Duration of Snow Accumulation Increases after Harvesting in Lodgepole Pine in Wyoming and Colorado

Howard L. Gary, Principal Hydrologist
Rocky Mountain Forest and Range Experiment Station[1]

CLEMSON UNIVERSITY LIBRARY
SEP 13 1979
SCI., TECH. & AGR. DIV.

North-south alternate stripcuts accumulated 15 to 60% more snow than similar widths of uncut forest. Part of the increase apparently resulted from redistribution of snow along the windward clearcut-forest interface. Data from a commercially clearcut area and 2H wide study plots indicated increased snow accumulation persists for decades, perhaps the life of the surrounding residual forest.

Keywords: Watershed management, land-use planning, clearcutting, snow hydrology, water yield management.

The 3.9 million acres (15,783 km^2) of lodgepole pine (*Pinus contorta* Dougl.) on commercial forest lands in Colorado and Wyoming occupy an important water producing zone and, thus, offer opportunities for complementing silviculture and water yield improvement practices. The recommended silviculture system for optimum redistribution of snow for water yield improvement in the lodgepole pine forests is clearcutting in small blocks or strips (Leaf 1975). The general prescription is blocks or strips less than 8 tree heights (8 H) in width, protected from wind and spaced at least 5 H apart. In some situations larger cutting units may be justified for disease control.

Studies of snow in lodgepole pine forests generally have shown greater quantities of snow in small openings and clearings and/or in thinned stands than beneath undisturbed forests (Niederhof and Dunford 1942, Wilm and Dunford 1948, Goodell 1952, Miner and Trappe 1957, Berndt 1965, and Dietrich 1973). These authors generally attribute accumulation differences to interception losses. A comprehensive study of the Fool Creek watershed in Colorado indicated no increase in snow as a result of alternate stripcutting but showed there was significant redistribution of snow from the undisturbed forest to the cut areas (Hoover and Leaf 1967). At present it is generally concluded forest openings and forest margins must be considered as a whole in evaluating effects of harvesting on snowpack accumulation (Anderson 1969, Gary 1974).

Dynamic simulation models of the long-term effects of forest and watershed management indicate water yield increases after small patch cuts may persist for at least 50 and perhaps 60 or more years (Alexander and Leaf 1975). However, the long-term effect and time trend of clearcutting in small blocks or strips on snow

[1]*Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

redistribution has not been generally validated. This study reports some long-term effects of harvesting on snow redistribution and the probable duration of the effects.

Study Area and Methods

Lodgepole forests in southern Wyoming are generally found at elevations between 2,450 and 3,500 m (Tackle 1959). Annual precipitation is generally greater than 450 mm, with one-half to three-fourths as snow which persists until about May. Similar elevations and precipitation patterns characterize lodgepole pine areas in Colorado. Lodgepole pine elevations in northern Wyoming are slightly lower.

The general study area was in an extensive forest of lodgepole pine in southern Wyoming. The area is on a gently rolling plateau about 2,740 m above sea level, well exposed to prevailing southwesterly winds. The area is usually snow-covered from late November to early May. Little melt occurs under the forest cover until April. Snowfall amounts are usually low but account for about one-half of the annual precipitation of 450 to 500 mm.

Snow Accumulation in Alternate Strips

Measurements were taken in an extensive and mature lodgepole pine stand which had been harvested for wood products by strip-cutting in 1955-1959. The strips were between 125 and 150 m wide and about 1.6 km long. Strips were oriented north-south, mainly on gentle southerly exposures. Today the cut strips are generally well stocked with lodgepole pine regeneration. Some have been thinned. Heights of new dominants and co-dominants in the strips range from 3 to 6 m. The leave strips of the remaining mature lodgepole pine stand averaged about 830 trees larger than 12.7 cm dbh per ha. Diameter averaged about 20.5 cm and basal area about 29.4 m^2/ha. The average height of the leave forest was about 15 m.

An east-west oriented snow measurement transect was established across four forested strips and four cut strips on a gently southfacing slope about 400 m from the ridgetop (fig. 1). A second east-west transect also was established across two forested strips and three cut strips on similar terrain on the adjacent

Figure 1.—Closeup of regeneration in one clearcut strip and adjacent forest in 1977.

north-facing slope, 100 to 200 m below the ridgetop. Sample points along transects were spaced about 10 m (0.5 chain) apart. Where necessary, distances were adjusted so sample points fell at each forest-clearing interface. The transect on the south-facing slope had 99 sample points and was about 1,000 m long. The transect on the north-facing slope had 68 sample points and was about 674 m long. Snow water equivalents were measured near the time of maximum snowpack (about mid-March), over a 3-year period from 1975 to 1977. All snow samples were obtained with a standard federal snow tube and weighed on a dial-type scale.

Simulated Duration of Effects of Harvesting on Snow

This part of the study simulated the duration of the effect of harvesting on snowpack accumulation. An even-aged stand (about 80 years old) located on level terrain was selected for study. The stand had been thinned in the late '30's by the Civilian Conservation Corps and had about 1,852 trees per ha. Tree diameters ranged from about 7.6 to 17.8 cm with an average of 12.7 cm. Basal area was about 23.8m^2 per ha. Average height of all trees was about 10.3 m.

Data were collected during the winters of 1975 and 1976. In October of 1974 a 2-H-wide clearing about 21 by 21 m was established. All trees and slash were removed from the cleared area. In an area about 25 m north of the first clearing all trees were cut down in a similar sized 2-H-wide area, leaving 1.22-m-tall stumps. A predetermined butt-end section, equivalent to one-half

of the original height (1/2 H) was removed from each of 85 trees. Each tree was then raised and bolted to its own stump (fig. 2).

In late October 1975 a third 2-H-wide plot was established 25 m north of the 1/2 H plot. In this plot one-fourth of the original height was removed from the butt-end of each tree (77 trees). The trees were then raised and bolted to their stumps to establish a new stand three-fourths as tall (3/4 H) as the surrounding forest. The tree sections not used in the 1/2 and 3/4 H plots were removed from the area. The needles on all the bolted up trees remained on the trees and were green and flexible until taken down early the next summer.

Eight east-west transect lines (equally spaced) were established across all plots and extended into the undisturbed forest on either side of the 2-H-wide clearing, the 1/2 H and the 3/4 H plots. Snow sampling points along the transects within treated areas were spaced 1.5 m apart. Sample point locations along the transect sections extending into the upwind (west) forest were 1.5, 3.0, 6.0, 12.0, and 18.0 m for each plot. Sample point spacing on the downwind (east) sides of the plots were the same, except two additional sample points were established at 24 and 30.5 on each transect.

Time-Trend of Effects of Harvesting on Snow

Snow data collected periodically over the last 30 years for a continuing study on the Fraser Experimental Forest in north central Colorado was also analyzed to determine time-trend of harvesting effects on snow-accumulation. Wilm and Dunford (1948) reported initial results of the commercial clearcut harvesting. They described the study area as having 740 to 988 trees/ha larger than 8.9 cm dbh. Maximum diameter was about 56 cm. Heights ranged from 10.7 to 25.9 m with a few valley-bottom trees over 30 m high. In 1940 four harvesting levels and one control were applied to 20 plots 2 ha in size within 4 randomized blocks. Treatments of most interest for the present study included the extremes in plots with commercial clearcutting of all trees larger than 24 cm in diameter and the plots with no logging.

Figure 2.—Canopy of the undisturbed forest and for trees reconstructed to one-half their original height (1/2 H). Method of bolting to stumps inset.

Results and Discussion

Snow Accumulation in Alternate Strips

Snow water equivalents for sample points along the two transects provided strong evidence that greater average quantities of snow were in the clearcut strips, even during the extremely dry winter of 1977 (fig. 3). Individual point-to-point snow samples were widely variable both within and between the alternate cut and leave strips. Some of the variation in the cut strips appeared to be the result of old slash holding snow against the prevailing southwest winds. In the forest small open spaces and the ragged character of the over mature canopy allowed the snowpack to accumulate in a variable pattern. The widely fluctuating point samples of snow-water equivalents along the transect in the alternate forest strips differed from the generally smooth pattern of point to point samples observed under an 80-year-old lodgepole pine stand in the same vicinity (Gary 1975).

Low snow accumulation near the windward clearcut-forest interfaces (fig. 3) was a common characteristic on both north and south aspects in the alternate strip area. The same pattern is also observed in clearings 1-H wide (Gary 1974). The apparent snow deficit zone along the windward edge of the forest leave strips was strongly influenced by wind. However, no definite excessive deposits of snow attributable entirely to wind transport were observed in the forest interior. For the local area in general dry soils were found at most clearing-forest interfaces during mid-winter. The dry soils apparently indicate early melting is not a major cause for the commonly observed snow deficit zones.

The magnitude and combination of wind processes transporting snow from the clearing-forest interface vary from storm to storm, but the effects are cumulative over winter and help produce the snow deficit zone. One hypothesis accounting for some of the snow deficit zone is that strong back eddies of airflow and saltation processes at the snow surface during and after each snowfall transport some snow away from the lee clearing-forest interface into the clearings. Cumulative snow buildup then occurs in the clearings in low windspeed zones (Gary 1975). Zones of low snow accumulation were not generally present along the windward forest-clearcut interfaces because wind velocities are reduced (fig. 3).

Differences in snow accumulation in the clearcut strips and leave forest strips are summarized in table 1. In all years and on both slope aspects water equivalents were larger in the clearcut strips. The greatest differences were on the south aspect (41 to 60% more snow) and were apparently the result of greater exposure to prevailing southwest winds. On the north aspect the clearcut strips had 15 to 30% more snow than did the adjacent undisturbed forest strips.

Table 1.—Average snow water equivalents in alternate clearcut and undisturbed forest strips on north and south aspects

Aspect and site	Number of samples	Water equivalent		
		1975	1976	1977
North aspect				
Clearcut strips (C)	40	229	229	91
Undisturbed forest (F)	28	183	175	79
Percent increase (C over F)		25	30	15
South aspect				
Clearcut strips (C)	55	218	198	102
Undisturbed forest (F)	44	155	124	66
Percent increase (C over F)		41	60	55

Simulated Duration of Effects of Timber Harvesting

The physical manipulation of tree heights provided some insight to the expected duration of the effects of patch cutting on snow accumulation. Snow water equivalents measured in the one small cut patch and on two nearby plots with adjusted tree heights are illustrated in figure 4. During both years the small clearing had about 30% more snow water equivalent than the upwind forest, but the characteristic snow deficit zone was also present along the leeward forest side of the clearing. The greater snow accumulation in the clearing itself appeared in large part to be caused by redistribution as a result of back eddies in the airstream above and at the snow surface both during the following storms. Reduced interception loss appeared to be another factor. Volume computations based on increased snow catch in the small clearcut and decreased snow catch along the leeward forest

Figure 3.—Snow water equivalents across several cut and leave strips on a south aspect for two contrasting years.

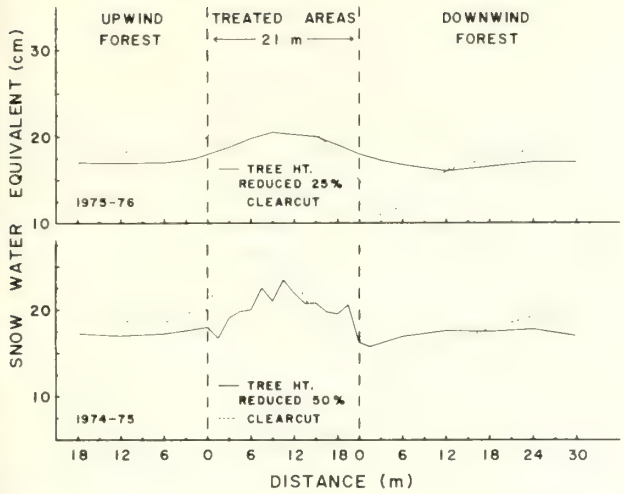


Figure 4.—Average maximum snow water equivalents in a 2-H-wide clearing during two winters and in 2-H-wide plots with tree heights reduced 1/2 H and 1/4 H.

border indicated a general equivalence between the greater and lesser snow accumulation zones (Gary 1974). The total measured increase in snow water equivalents attributed to the small clearcut plot for each of two winter seasons was less than 10 mm.

In the 1/2-H plot the lower branches of the crown of most trees were just above ground level. Snow sliding off of the crowns following storms accumulated mainly between trees, producing the uneven snow water equivalents in figure 4. Volume computations based on comparison with adjacent upwind and downwind forest indicated a 14% increase in snow catch (25 mm of water equivalent) inside the 1/2-H plot. Snow catch inside the 3/4-H plot averaged 13% more snow (23 mm more snow water equivalent) than was measured in the undisturbed forest.

The greater quantities of snow observed inside the adjusted-tree-height plots do not appear to be the result of redistribution processes, since the leeward snow deficit zones were not evident. The greater snow was apparently due to cumulative differential evaporation and/or sublimation losses between snow held by the undisturbed forest canopy and the protected lower level canopies over the 1/2- and 3/4-H plots.

The increased snow water equivalents in the small 2-H-wide clearcut plot and in the 1/2- and 3/4-H plots generally illustrated that small patches cut in lodgepole pine increase snow accumulation. The small 2-H-wide adjusted tree height plots also indicated increased snow accumulation will persist for several decades through the development of a new stand. After developing an age-height curve for lodgepole pine in the local area and by extrapolating from observed data in fig. 4, it was possible to illustrate the expected duration of snow redistribution in a small patch cut (fig. 5). For purposes of illustration, a patch cut about 2 H wide was made in a 90-year-old lodgepole pine stand. It was further assumed forest regeneration occurred within 1 year (complete regeneration would probably take up to 10 years or longer). The age-height curve for the new stand is the same as shown for the residual forest, except for displacement in time. It was also assumed the growth and management of the new stand will be similar to that in the residual forest.

Snow water equivalents (observed in fig. 4) the year after making the small patch cut show a 30% increase as the result of snow redistribution processes (fig. 5). When the new stand

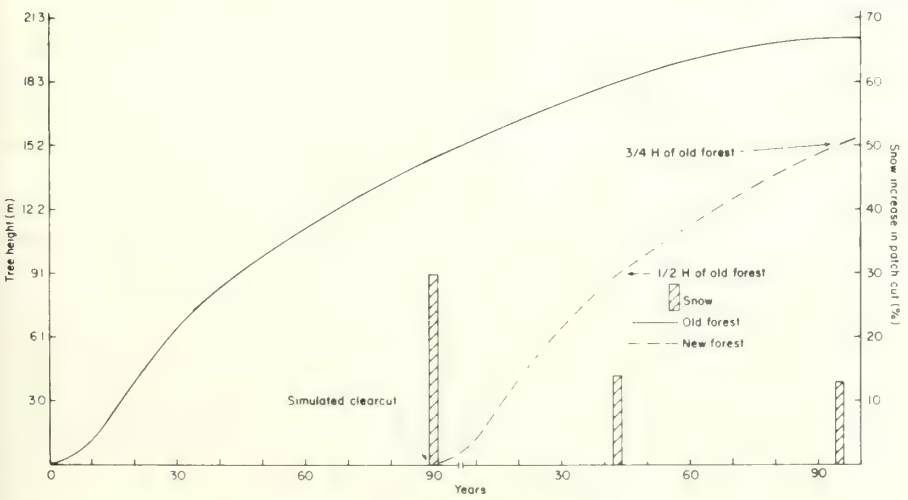


Figure 5.—Age-height curve for old-growth lodgepole pine, simulated forest regeneration after patch cutting a 2-H-wide area and the probable long-term duration of increased snow accumulation.

reaches 1/2 H of the residual forest, some 40 years later, the snow catch is only 14% higher than in the residual forest. About 90 years after establishing the new stand (when the new stand is about 3/4 of the residual forest) the snow catch would be about 13% above that expected in the residual forest.

The data contained in figure 5 are subjective, but illustrate the probable long-term duration of patch cuts made to increase snow accumulation. Based on past research and other small clearcuts in the area, the simulated curves were generally applicable for small patches up to about 5 H wide.

Time-Trend of Effects of Timber Harvesting

Snow measurements taken periodically over a period of 38 years at 100 sample points in plots commercially clearcut and plots left uncut on the Fraser Experimental Forest are summarized in figure 6. In the preharvest period 1938-39 snow water equivalents averaged 11% greater over the plots later selected for commercial clearcutting. However, based on five measurement periods spaced over the last 21-year period (1956-1976), plots commercially clearcut in 1940 averaged about 37% greater snow water equivalents than the plots not harvested. The difference of 58 mm was significant at the 0.01 level. Analysis of variance for all data collected since harvesting in 1940 also indicated no significant treatment-year interaction. Total annual growth increments in the first 20-year period after treatments were almost as great on the clearcut as on the uncut areas (Alexander 1966). However, differences in stand structure between the clearcut and uncut areas are today visually apparent, and the trend of increased snow accumulation as a result of the commercial clearcutting will apparently persist for many more years.

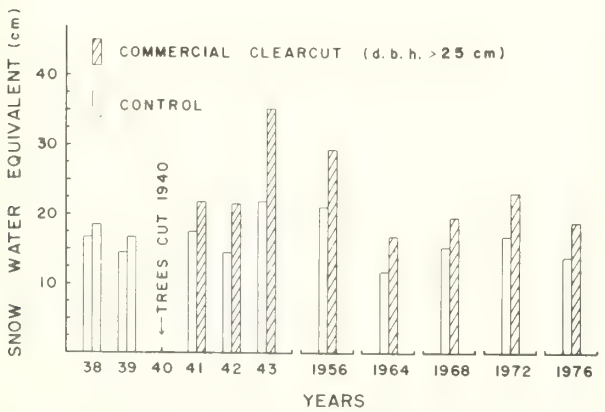


Figure 6.—Average snow accumulation over time for commercially clearcut and uncut lodgepole pine on the Fraser Experimental Forest.

Summary and Conclusions

Data collected for three winters in alternate clearcut strips harvested about 25 years ago and in the leave forest strips showed 15 to 60% more snow in the harvested strips. Part of the increase in clearcut strips apparently resulted from redistribution of snow from lee forest strips. It is not known what effect the snow deficit zone in the lee forest had on subsequent tree growth.

Data from the 2-H-wide clearcut plot, the 1/2- and 3/4-H plots showed the pattern of increased snow accumulation will apparently be maintained during regeneration for several decades after harvesting, probably until the surrounding residual forest is harvested.

Observations from the Fraser Experimental Forest generally indicated new forest growth has little diminishing effect on increased snow accumulation for several decades following. However, due to new tree growth and increasing biomass in the commercially clearcut area, the greater quantities of snow probably do not imply sustained increases in streamflow of the same magnitude.

In the lodgepole pine type in Colorado and Wyoming harvesting timber in small patches and in narrow strips less than about 8 H wide caused accumulation of at least 30% more snow than surrounding forest. However, much of the increase was at the expense of snow accumulation along the lee forest borders. The increased snow accumulation pattern will apparently persist for several decades after regeneration of a new stand. Greater water yields can be expected from clearcut areas for many many years, apparently because of reduced transpiration losses, a greater unit-area concentration of snowmelt water, and greater year-to-year carryover of soil moisture.

Literature Cited

Alexander, Robert R. 1966. Harvest cutting old-growth lodgepole pine in the central Rocky Mountains. J. For. 64:112-116.

Anderson, Henry W. 1969. Snowpack management. *In* Snow. p. 27-40. Oreg. State Univ., Water Resour. Inst., Seminar WR 011.69. [Corvallis, 1969.]

Berndt, H. W. 1965. Snow accumulation and disappearance in lodgepole pine clearcut blocks in Wyoming. J. For. 63:88-91.

Dietrick, Thomas S. 1973. Management of Colorado mountain lands for increasing water yields, Vol. 2-Hydrologic effects of patch cutting of lodgepole pine. Final Rep. No. CSU-14-06-D-6598-2 to U.S. Bur. Reclam., Div. Gen. Res., Denver, Colo., 95 p.

Gary, Howard L. 1974. Snow accumulation and snowmelt as influenced by a small clearing in a lodgepole pine forest. Water Resour. Res. 10:328-353.

Gary, Howard L. 1975. Airflow patterns and snow accumulation in a forest clearing. West. Snow Conf. Proc. 43:106-113. [Coronado, Calif., April 1975].

Goodell, B. C. 1952. Watershed management aspects of thinned young lodgepole pine stands. J. For. 50:374-378.

Hoover, Marvin D., and Charles F. Leaf. 1967. Process and significance of interception in Colorado subalpine forest. p. 213-224. *In* W. E. Sooper and H. W. Lull (ed.), Forest Hydrology, 813 p. Pergamon Press, N. Y. [Int. Symp. For. Hydrol., Univ. Park, Pa., Aug.-Sept. 1965]

Leaf, Charles F. 1975. Watershed management in the Rocky Mountain subalpine zone: The status of our knowledge. USDA For. Serv. Res. Pap. RM-137, 31 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Leaf, Charles F., and Robert R. Alexander. 1975. Simulating timber yields and hydrologic impacts resulting from timber harvest on subalpine watersheds. USDA For. Serv. Res. Pap. RM-113, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

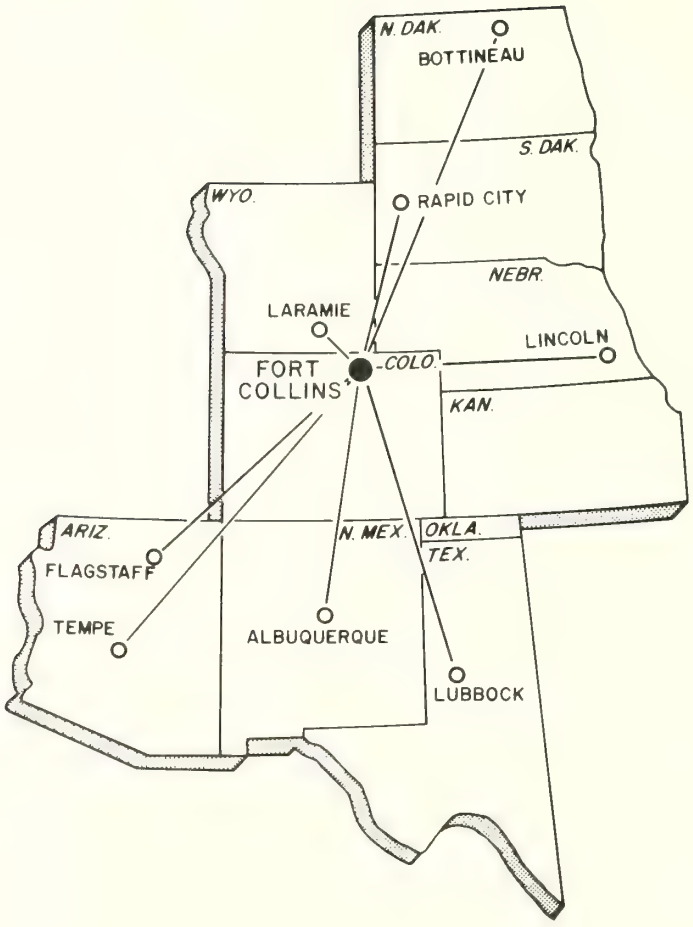
Miner, N. H., and J. M. Trappe. 1957. Snow interception, accumulation, and melt in lodgepole pine forests in the Blue Mountains of eastern Oregon. U.S. Dep. Agric., For. Serv., Pac. Northwest For. and Range Exp. Stn., Res. Note 153, 4 p.

Niederhof, C. H., and E. G. Dunford. 1942. The effects of openings in a young lodgepole pine forest on the storage and melting of snow. J. For. 40:802-804.

Tackle, David. 1959. Silvics of lodgepole pine. U.S. Dep. Agric., For. Serv., Intermt. For. and Range Exp. Stn., Misc. Publ. 19, 24 p.

Wilm, H. G., and E. G. Dunford. 1948. Effect of timber cutting on water available for streamflow from a lodgepole-pine forest. USDA Tech. Bull. 968, 43 p.

Agriculture — CSU, Fort Collins


N. DAK.
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

l 1979

RESEARCH NOTE RM-367

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Mountain Pine Beetle Infestation Characteristics in Ponderosa Pine, Kaibab Plateau, Arizona, 1975-1977

CLEMSON UNIVERSITY LIB
SEP 13 197
SCI., TECH. & AGR. DIV.

Douglas L. Parker[1] and Robert E. Stevens[2]

A moderate mountain pine beetle infestation was characterized in standing and downed trees by low attack density, normal egg gallery length, and normal egg numbers. Larger trees produced more brood per unit surface area than smaller trees, and were infested to a greater height. Felled trees were attacked as heavily as standing trees. Trap trees might be used here to augment other beetle management approaches.

Keywords: Insect control, Scolytidae, *Dendroctonus ponderosae, Pinus ponderosa*

From 1973 to 1977, the mountain pine beetle (MPB) caused heavier than usual mortality in the old-growth ponderosa pine forest on the Kaibab Plateau in northern Arizona. Tree killing was most severe on the Kaibab National Forest, but the outbreak also affected stands in the adjacent Grand Canyon National Park.[3]

MPB activity is not new to the area. Blackman (1931) reported evidence of the following outbreaks: 1837-1846, 1853-1864, 1878-1882, 1886-1892, 1906-1910, and 1916-1926; the two most severe and widespread outbreaks were from 1886 to 1892 and 1916 to 1926. Localized tree mortality occurred from 1935 to 1938 and again in 1950.[4]

In 1973, groups of dead ponderosa pine were detected near East Lake. Surveys over a 4,000-acre area showed that trees were killed at a low but increasing level during 1971 and 1972. The infestation increased from about 2 trees per acre in 1973 to about 4.5 trees per acre in 1974, and assuming no control action, further increases were

[1]*Entomologist, Southwestern Region, USDA Forest Service, Albuquerque, N. Mex.*

[2]*Entomologist, Rocky Mountain Forest and Range Experiment Station. Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3]*Parker, Douglas L. Biological evaluation, mountain pine beetle in ponderosa pine, North Kaibab Ranger District, Kaibab National Forest, Arizona, 1975. USDA For. Serv., Southwest. Reg., Albuquerque, N. Mex., Unpubl. Rep. R-3, 76-4, 7 p.*

[4]*Parker, Douglas L., and Robert E. Acciavatti. Biological evaluation and damage survey, mountain pine beetle in ponderosa pine, Kaibab Plateau, Kaibab National Forest, Arizona, 1975. USDA For. Serv., Southwest. Reg., Albuquerque, N. Mex., Unpubl. Rep. R-3, 75-24, 11 p.*

predicted for 1975. Infested trees were logged in the East Lake Timber Sale area in 1975 in an effort to suppress the outbreak, and a similar logging program was carried out again in 1976. Generally the logging was considered effective in reducing the density of beetle-attacked trees in the treatment area, but widely scattered trees were killed over about 75,000 acres.[3] The infestation declined throughout the entire area in 1977 and 1978.

Blackman (1931) studied the mountain pine beetle intensively on the Kaibab Plateau during the summers of 1925 and 1926. Essentially no research had been done on MPB in Arizona since, and the 1973 outbreak provided an opportunity to compare infestation characteristics with those reported by Blackman, and also to investigate the practice of using trap trees as a control technique, an approach he discussed briefly.

We observed MPB on the Kaibab Plateau in 1975, 1976, and 1977, in both standing and felled trees. Observations in standing trees included the relationship of attacks and brood production with respect to (a) tree height, (b) aspect (north or south), and (c) tree diameter. We also looked at Knight's (1960) method for predicting MPB trends, developed in Colorado and the Black Hills, for applicability to the Kaibab situation. Finally, we investigated the relationship between tree diameter and height of infestation.

Methods

Sample trees were selected at various locations in the Kaibab National Forest near Jacob Lake, Coconino County, Arizona, T36 and T37N. Trees were sampled during the period June 8-12, 1975; June 22-24, 1976; and on September 27 and 28, 1977.

Standing trees.—In 1975 and 1976 we sampled 30 standing trees infested the previous seasons. Standing trees were not sampled in 1977. Trees were felled, limbed, and bucked into sections as necessary to permit rolling. Bark samples, 6 by 6 inches square, were taken from the north (N) and south (S) sides at 5 feet above the ground line and thereafter at 10-foot intervals as high as evidence of MPB infestation could be found. From each sample we recorded (a) number of attacks as indicated by beginnings of egg galleries, (b) total length of egg galleries, and (c) number of living insects (generally larvae).

Felled (trap) trees.—Trap trees were sampled the same as standing trees; however fewer trees were sampled, and diameter classes were not established. Instead of N-S, top and bottom of the log were the two aspect variables chosen for sampling. Trap trees sampled in 1975 were pushed over by bulldozers during road building operations about 1-2 months prior to beetle flight. Some pushed-over trees still had root contacts, but most had none. Trap trees were felled in early July of 1976 and 1977, prior to the onset of the MPB attack period. All trap trees sampled were in the East Lake Timber Sale area, on Tater Ridge and Dog Point.

Where appropriate, data were subjected to analysis of variance for an unbalanced design. Differences were significant at the 0.05 level.

Results and Discussion

Standing Trees

Attack density.—The attack density patterns observed, from 0.77 to 4 attacks per square foot (table 1), are light for MPB in ponderosa pine. Blackman (1931), working in the same area, reported from 4 to 9 per square foot, with an

Table 1.—Mean attack and brood density, and egg gallery length, mountain pine beetle in standing ponderosa pine, Kaibab Plateau, Arizona, 1975-1976

	Number of trees		Number of samples		Attack density		Length egg gallery		Brood density	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
					no./ft²		*in/ft²*		*no./ft²*	
Diameter class										
1 (11-15")	9	4	70	30	1.5	1.7	84.6	90.6	16.0	22.8
2 (16-20")	9	12	86	90	1.5	2.8	93.7	91.2	24.0	34.5
3 (20"+)	10	7	108	76	2.4	4.0	101.1	118.1	32.4	73.8
Side of tree										
North	28	23	132	98	1.7	3.5	95.9	100.0	29.7	50.7
South	28	23	132	98	1.4	3.0	92.1	100.8	20.1	53.6
Sample height										
5'	28	23	56	46	1.5	3.3	91.9	107.4	29.4	68.3
15'	28	23	56	46	2.6	3.4	100.1	110.4	26.2	46.5
25'	27	21	54	42	3.2	3.6	98.7	113.6	16.5	40.3
35'	25	15	50	30	1.4	2.9	81.2	83.3	23.6	52.6
45'	13	10	26	20	.8	3.0	103.2	86.6	26.9	39.7
55'	6	4	12	8	2.0	2.5	90.5	80.9	48.0	8.5
65'	4	1	8	2	1.3	4.0	87.5	72.8	58.0	81.0
75'	1	0	2	0	—	—	136.5	—	34.0	—

Table 2.—Infestation heights (in feet) and stem diameters (in inches), mountain pine beetle in standing ponderosa pines, Kaibab Plateau, Arizona, 1975-1976

Year	Number of trees	Tree diameter at breast height		Height at upper limit of infestation		Tree diameter at upper limit of infestation	
		Mean	Range	Mean	Range	Mean	Range
1975	28	19.5	12.4 - 42.5	42.5	15-75	11.3	6.8 - 19.4
1976	23	18.7	11.0 - 38.1	35.0	15-65	12.0	7.5 - 16.4

average of about 5.75. Schmid (1972) reported means more or less similar to those of Blackman in the Black Hills in 1965 and 1966. W. F. McCambridge[5] indicated that the MPB attack density pattern in the current Colorado Front Range infestation (also in ponderosa pine) ran consistently around eight attacks per square foot.

The attack density observed both years was so variable—in most cases the coefficient of variation was over 100% due to many zero counts—that standard statistical procedures were not generally useful. However the 1976 data, after eliminating the poorly represented 55- and 65-foot heights, showed that mean attack density varied significantly only by diameter class, i.e., number of attacks increased linearly with increase in diameter size. No variation was indicated with side of tree (N or S) or height of sample. No interactions between diameter class, aspect, or sample height were evident. Inspection of the 1975 data indicates a similar general pattern; however, the attack density-diameter class relationship is inconsistent.

Egg gallery length.—Even though the attack density was low, the inches of egg gallery per square foot, which provides an indication of egg production, appears relatively high (table 1). There was an average of about 93 inches of egg gallery per square foot in trees sampled in 1975, and 100 inches in 1976. These measurements are comparable to average lengths recorded by Schmid (1972) and McCambridge[5] where attack densities were higher; Blackman (1931) did not discuss egg gallery lengths. It appears that the low attack density was offset by increased egg gallery construction and egg laying.

Brood density.—Data for brood density (table 1) were similarly characterized by high variability. Average brood density was considerably higher than that reported by Blackman (1931), who cited averages of 5.3 and 2.32 beetles per square foot in 1925 and 1926, respectively. However, Blackman referred to "beetles," and our insects were, in many cases, still in the larval stage. Additional mortality could have been expected before most of the insects reached the adult stage. Therefore our results are probably not comparable to Blackman's. Also Blackman's studies were conducted during the population collapse phase of an outbreak; the current study was conducted during what we considered early stages of an outbreak.

Analysis of the 1976 data revealed significant differences in brood numbers versus diameter class, i.e., the large trees showed greater brood density both years. Aspect and sample height were not significant. Aspect did show a difference in 1975, and density was greater on the north sides of the trees.

Height of infestation and associated stem diameters.—As expected, larger trees were infested to a greater height (fig. 1). Mean height of infestation was 42.5 feet in 1975 and 35.0 feet in 1976 (table 2). These figures are similar to those of Blackman (1931), who reported an average height of infestation (137 trees) of 39.5 feet. Mean tree diameter at the upper limit of infestation in our study was about the same both years, 11.3 and 12.0 inches.

Infestation trend.—Efforts to test the applicability of Knight's (1960) sequential sampling scheme to the Kaibab situation yielded results as follows: the 1975 data (samples from 5 feet only; 56 samples, 379 insects) fall in the "no decision" zone between a static and an increasing trend (90% confidence interval). In practice when this occurs, the trend is considered to be increasing. The 1976 data (46 samples, 775 insects) indicate an increasing trend. Aerial detection survey records show that tree mortality remained about static from 1975 to 1976, while tree losses decreased from 1976 to 1977. Logging of infested trees can be presumed to have altered the situation and may be, at least in part, responsible for the loss trend not following what would have been predicted. The sequential sampling

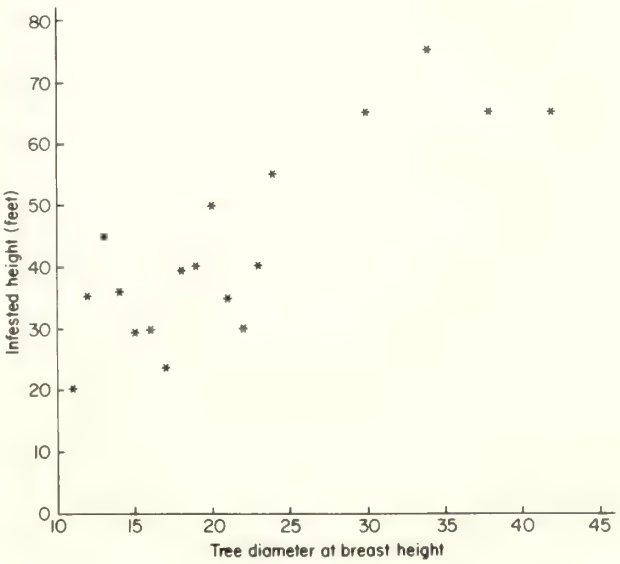


Figure 1.—Mean infestation heights and tree diameters, Kaibab Plateau, Arizona, 1975-1976. (N=51)

[5]*Personal communication, W. F. McCambridge, Entomologist, Rocky Mt. For. and Range Exp. Stn., Fort Collins, 1977.*

Table 3.—Mean attack and brood density and egg gallery length, mountain pine beetle in ponderosa pine, trap trees, Kaibab Plateau, Arizona, 1975-1977

	Number of trees			Number of samples			Attack Density			Length of egg gallery			Brood density		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	[1]1977
							no./ft²			in/ft²			no./ft²		
Side of tree															
Top	16	13	22	98	61	163	0.9	3.1	0.4	44.5	55.5	7.8	16.7	5.2	—
Bottom	16	13	22	98	61	163	2.5	3.5	3.0	66.9	67.5	51.9	36.4	7.5	—
Sample height[2]															
5′	16	13	22	32	26	44	2.6	4.8	2.0	77.9	91.5	33.6	24.6	15.9	—
15′	15	13	22	30	26	44	1.9	3.4	1.8	59.6	86.9	28.8	25.5	2.9	—
25′	15	12	20	30	24	40	0.9	4.0	1.6	59.7	72.3	29.4	25.2	4.2	—
35′	15	11	13	30	22	26	1.3	2.2	1.7	61.4	49.4	28.8	30.7	5.1	—
45′	14	8	7	28	16	14	1.0	1.8	1.1	49.9	40.2	29.4	23.8	3.7	—
55′	10	2	4	20	4	8	1.4	5.0	1.5	43.4	57.0	25.0	38.5	0	—
65′	7	2	1	14	4	2	.9	0	2.0	27.1	45.0	14.0	22.0	0	—
75′	3	0	0	6	0	0	0	—	—	30.7	—	—	11.3	—	—
85′	1	0	0	2	0	0	0	—	—	24.0	—	—	4.0	—	—

[1]*Brood density not recorded in 1977.*
[2]*Distance toward top of tree from original ground line; top and bottom samples combined for each height.*

scheme was inadequately tested to tell with confidence if it is or is not of value for predicting MPB infestation trends in Kaibab Plateau ponderosa pine.

Trap Trees

Attack density.—Mean attack densities were low, ranging from 1-2, 1-5, and 1-2 per square foot in 1975, 1976, and 1977, respectively (table 3). Each year's data showed great variability, largely resulting from many samples having no attacks. Attack densities in trap trees were generally comparable to densities in standing trees. Analysis of the slightly less variable 1976 data, again eliminating the poorly represented heights above 45 feet, showed a generally decreasing attack density with height. No differences were indicated between top and bottom of logs in 1976; however, major differences were recorded in 1975 and 1977. Attack density in 1976 was about double that in 1975 in the lower part of the sample logs; this was accompanied by much less variability.

Brood density.—Brood density patterns in the trap trees were similar to those in the standing trees in 1975 (table 3) but dropped markedly in 1976. The reasons for this are not known conclusively but the increased attack density may have been a factor. Analysis of the brood data (both years) showed significantly more brood was produced on the undersides of the logs. No differences were associated with position along the length of the tree.

Overall, the data support Blackman's (1931) contention that trap trees may provide a useful means for reducing low level MPB populations in the Kaibab area. Trap trees were attacked and did take a portion of the flying beetles out of the population. Recently felled trap trees appear to be highly attractive to the beetle. In one instance, five trap trees were cut at a location more than 1/4 mile from the nearest known infested trees and all five were attacked. Adjacent standing trees were never attacked. Land managers might consider this approach, alone or combined with logging of infested trees and other appropriate measures, when the next MPB outbreak occurs in the Kaibab area.

Literature Cited

Blackman, M. W. 1931. The Black Hills beetle (*Dendroctonus ponderosae* Hopk.). Bull. N.Y. State Coll. For. Vol. IV, No. 4, Tech. Publ. 36, 97 p.

Knight, F. B. 1960. Sequential sampling of Black Hills beetle populations, U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 48, 8 p.

Schmid, J. M. 1972. Emergence, attack densities, and seasonal trends of mountain pine beetle (*Dendroctonus ponderosae*) in the Black Hills. USDA For. Serv. Res. Note RM-211, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

1979

RESEARCH NOTE RM-368

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

Energy Potential from Central and Southern

ERRATA SHEET

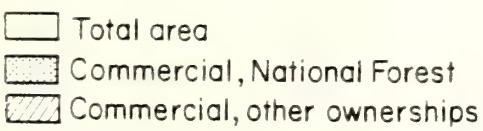
for

USDA Forest Service Research Note RM-368

Energy Potential from Central and Southern
Rocky Mountain Timber

George R. Sampson

On page 2, figure 1, the legend for the figure should be as follows:



areas as well as qualifying areas examined under the Forest Service Roadless Area Review

[1]*Presented at the Colorado State University Natural Resource Days, March 10, 1978, in Fort Collins.*

[2]*Market Analyst, Rocky Mountain Forest and Range Experiment Station, central headquarters maintained in Fort Collins in cooperation with Colorado State University*

Traditional growth data is based only on the bole of trees. Since branches, tops, and needles can be utilized for energy, the estimate of sustainable energy potentials derived in this study (fig. 2) includes a 40% increase over bole volume. The resulting cubic foot volume was multiplied by 25 to convert to dry weight in pounds per green cubic foot (25 was arbitrarily

Table 3.—Mean attack and brood density and egg gallery length, mountain pine beetle in ponderosa pine, trap trees, Kaibab Plateau, Arizona, 1975-1977

	Number of trees			Number of samples			Attack Density			Length of egg gallery			Brood density		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	[1]1977
							no./ft²			*in/ft²*			*no./ft²*		
Side of tree															
Top	16	13	22	98	61	163	0.9	3.1	0.4	44.5	55.5	7.8	16.7	5.2	—
Bottom	16	13	22	98	61	163	2.5	3.5	3.0	66.9	67.5	51.9	36.4	7.5	—
Sample height[2]															
5′	16	13	22	32	26	44	2.6	4.8	2.0	77.9	91.5	33.6	24.6	15.9	—
15′	15	13	22	30	26	44	1.9	3.4	1.8	59.6	86.9	28.8	25.5	2.9	—
25′	15	12	20	30	24	40	0.9	4.0	1.6	59.7	72.3	29.4	25.2	4.2	—
35′	15	11	13	30	22	26	1.3	2.2	1.7	61.4	49.4	28.8	30.7	5.1	—
45′	14	8	7	28	16	14	1.0	1.8	1.1	49.9	40.2	29.4	23.8	3.7	—

1979

RESEARCH NOTE RM-368

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT

Energy Potential from Central and Southern Rocky Mountain Timber[1]

George R. Sampson[2]

CLEMSON UNIVERSITY LIBRARY
SEP 13 1979
SCI. TECH.

Low energy per unit of weight and high cost relative to coal limit wood as a major energy source in the central and southern Rocky Mountains. Without markets for higher uses, residues can provide heat, steam, or electricity. Uses will depend on improved technology and harvest efficiency.

Keywords: Energy, timber residues

Introduction

It might be supposed potential is fairly high for utilizing wood for energy in the central and southern Rocky Mountain states (South Dakota, Wyoming, Colorado, Arizona, and New Mexico). Forest land area per resident is high compared to the remainder of the United States. Figure 1 shows total area of forest land and commercial forest land for each state involved. Forest land is land at least 16.7% stocked by forest trees of any size or formerly having such tree cover and not currently developed for nonforest use. Commercial forest land is forest land not withdrawn from timber utilization and having the capability of producing more than 20 cubic feet of wood per acre (1.4 m^3/h) per year. Commercial forest land represented in figure 1 includes currently inaccessible and inoperable areas as well as qualifying areas examined under the Forest Service Roadless Area Review and Evaluation II (RARE II). Not inlcuded in commercial forest land are existing Wilderness Areas, National Parks, and other permanently reserved areas. Areas of commercial forest land within National Forests are shown in figure 1.

Energy Potential with Maximum Growth

Theoretically, the maximum sustainable energy production of central and southern Rocky Mountain commercial forest lands is directly determined by sustainable wood growth under maximum forest production. Current growth levels on commercial forest lands are much lower than potential growth. Nevertheless, annual removals are well below actual growth, except in Arizona.

Traditional growth data is based only on the bole of trees. Since branches, tops, and needles can be utilized for energy, the estimate of sustainable energy potentials derived in this study (fig. 2) includes a 40% increase over bole volume. The resulting cubic foot volume was multiplied by 25 to convert to dry weight in pounds per green cubic foot (25 was arbitrarily

[1]*Presented at the Colorado State University Natural Resource Days, March 10, 1978, in Fort Collins.*

[2]*Market Analyst, Rocky Mountain Forest and Range Experiment Station, central headquarters maintained in Fort Collins in cooperation with Colorado State University*

chosen to represent the average of Rocky Mountain timber species, which range from 20 to 29 pounds dry weight per green cubic foot). This weight was then converted to British Thermal Unit (BTU) equivalents by multiplying by 8,500 (8,500 BTU's per pound of dry wood is an energy conversion factor in general use). Table 1 shows typical heating values for wood and bark of Rocky Mountain species. The energy equivalent of this total timber harvest is compared with the estimated energy consumption by state in figure 3 (consumption does not include firewood and other minor energy sources such as animal wastes). Consumption estimates were derived from national estimates by using the proportion of population in each state to national population as a basis (Baldwin et al. 1974). The total potential energy available from wood is less than 15% of combined annual energy consumption in these states.

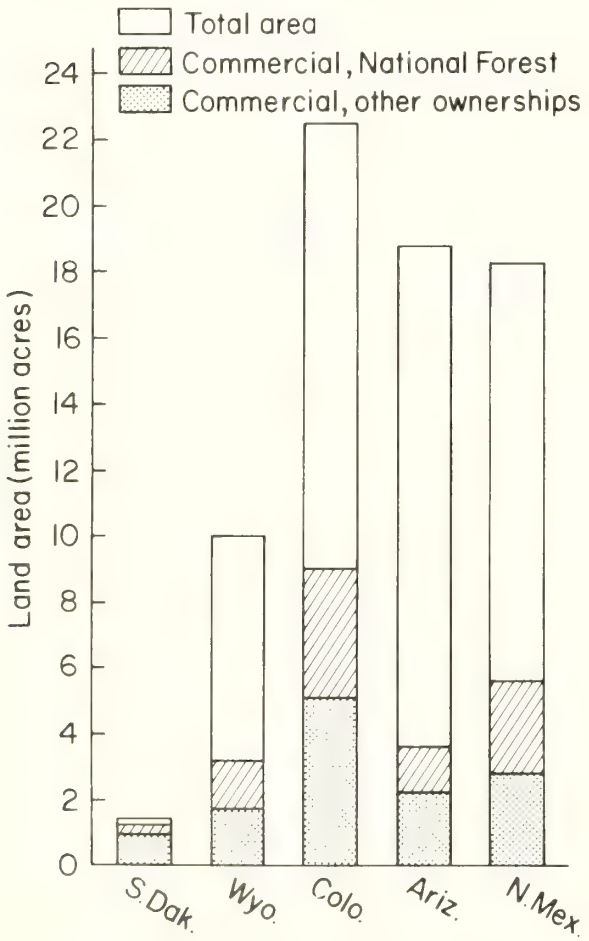


Figure 1.—Forest land area and commercial forest land area by state within study area. (Adapted from Green and Setzer 1974).

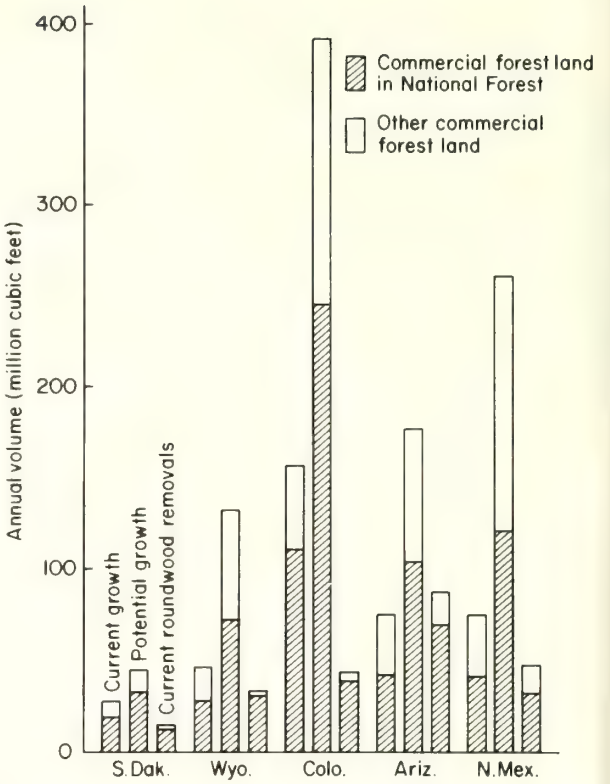


Figure 2.—Current annual growth, potential annual growth, and roundwood removals in 1974 by state. (Adapted from Green and Setzer 1974)

This does not mean we should forget about wood as an energy source. Wood has several significant advantages. It is a low sulfur fuel that can be burned for energy without very costly antipollution devices. A wood-fueled system also has less total emissions per unit of energy output than a system using physically cleaned coal or low sulfur western coal (Hall 1976). Another consideration is that pressure is growing rapidly to seek out and utilize all economical sources of energy. Wood's renewability, as compared with fossil fuels, is particularly attractive.

Table 1.—Typical heating values for wood and bark of Rocky Mountain species

Species	Heating value per dry pound	
	Wood	Bark
	BTU	*BTU*
Douglas fir	[1]9,200	[1]10,100
Lodgepole pine	[1]8,600	[1]10,760
Ponderosa pine	[1]9,100	[2] 9,100
Englemann spruce	—	[3] 8,820
True firs	[1]8,300	—

[1]*Dobie and Wright (1975)*
[2]*Grantham, et al (1974)*
[3]*Corder (1973)*

The remainder of this paper is a discussion of several parameters to help identify economic opportunities for utilizing wood for energy.

Economics of Using Wood as Fuel

For wood to be an economical choice as fuel, two economic tests must be met. First, wood must be a cheaper source of energy than competing fuels. Second, use of wood as a fuel must be more profitable than use of wood for other purposes.

Energy Potential of Timber

Volume of current removals of timber for energy generation purposes is not known. Most removals are probably for use in fireplaces with a very small amount for use in stoves. Much of the firewood from National Forests is removed under free-use arrangements, and there are no estimates of the volumes removed from other ownerships.

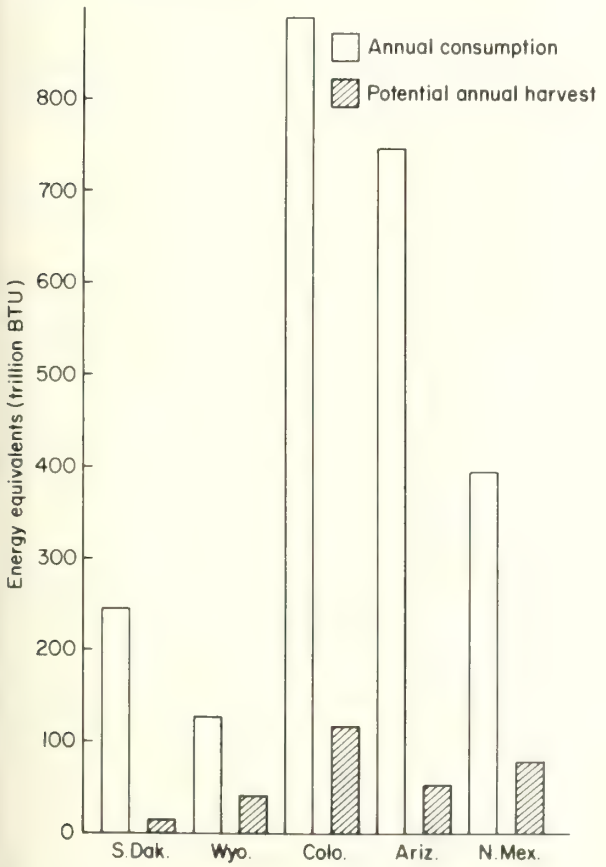


Figure 3.—Estimated annual consumption of energy (1973 data) and energy from potential annual timber harvest from commercial forest land. (Derived from population estimates and data in Baldwin et al. 1974)

For the Rocky Mountain area the major energy source competing with wood-based energy is coal. In terms of technology, coal and wood are interchangeable for energy generation. Therefore, the cost of wood and the environmental impact of its use relative to coal will determine if and where wood can be economically used as an energy source. The current delivered coal price for high volume users such as electric generating plants is $9 per ton ($9.92/metric ton) in the Black Hills and up to $16 per ton ($17.63/metric ton) in Colorado's Front Range. With conventional systems of timber harvesting in the Rocky Mountains, very little wood can be brought in at a comparable cost unless benefits to land management are included.

For example, based on Forest Service estimates the cost of getting Black Hills timber to a woods landing, excluding the cost of roads, brush disposal, and the like, would be about $7-$8 per green ton ($7.72-$8.82/metric ton). Costs of hauling to the energy conversion plant and any required handling or processing must be added to falling and yarding costs. Cost comparisons for accumulating wood and coal on a potential energy basis are shown in figure 4. Where the energy user is relatively close to a coal mine, coal will almost certainly be a cheaper fuel. Locations in the Rocky Mountains are close to both coal and timber; locations in New England are close to timber but far from coal. So in the Northeast, harvesting and burning timber may be an economically viable alternative for generating electricity, while the potential for harvesting timber in the Rocky Mountains for energy is less favorable due to the presence of cheaper energy sources.

Higher harvesting and hauling costs can be tolerated for other forest products than for energy. Timber value at a Rocky Mountain mill before processing is more than $120 per thousand board feet or about $50 per ovendry ton ($55.12/metric ton). This price is for the whole log, only one-third of which is likely to end up as lumber. Thus, that portion of the log that ends up as finished lumber is worth over $150 per ovendry ton ($165.35/metric ton). Current market prices for pulpwood, fence

posts, and poles also justify harvesting and transportation costs substantially higher than energy uses could sustain.

Future levels of use of timber for energy beyond what is used in fireplaces for esthetic purposes will depend on changes in technology which will allow harvesting of wood for energy at lower costs. Dramatic increases in alternative energy sources such as natural gas, fuel oil, and coal might also result in more timber being used for energy.

Energy Potential of Mill Residues

Residues from primary forest products provide a more economical source of energy from wood because harvesting and transportation costs are charged to the primary product. This usually makes mill residues a cheaper energy source than coal (and it is also cheaper than oil or natural gas if only variable costs of the fuels are considered). Mill residues can even be hauled short distances and still be cheaper than coal as shown in figure 4.

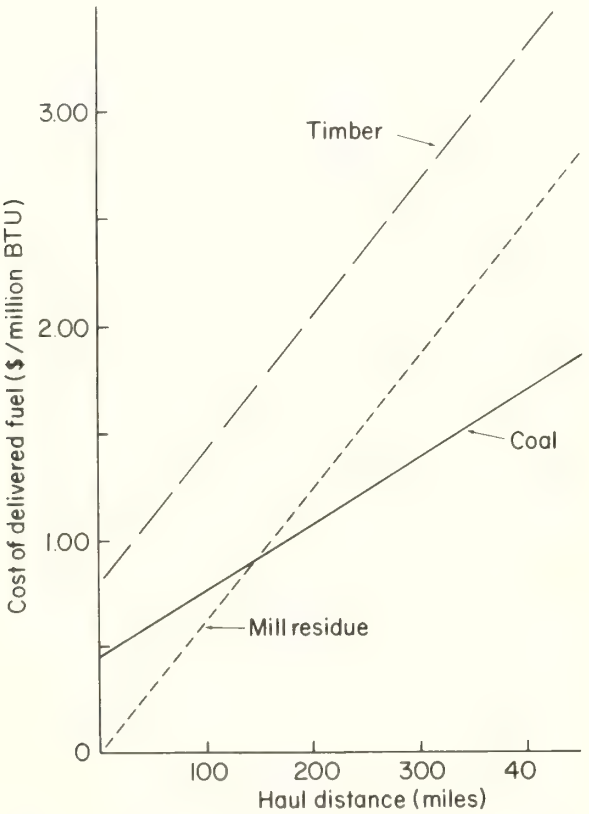


Figure 4.—Cost of energy from timber, coal, and forest products industry residue by haul distance. (Transportation cost of $0.0625 per ton-mile for all materials)

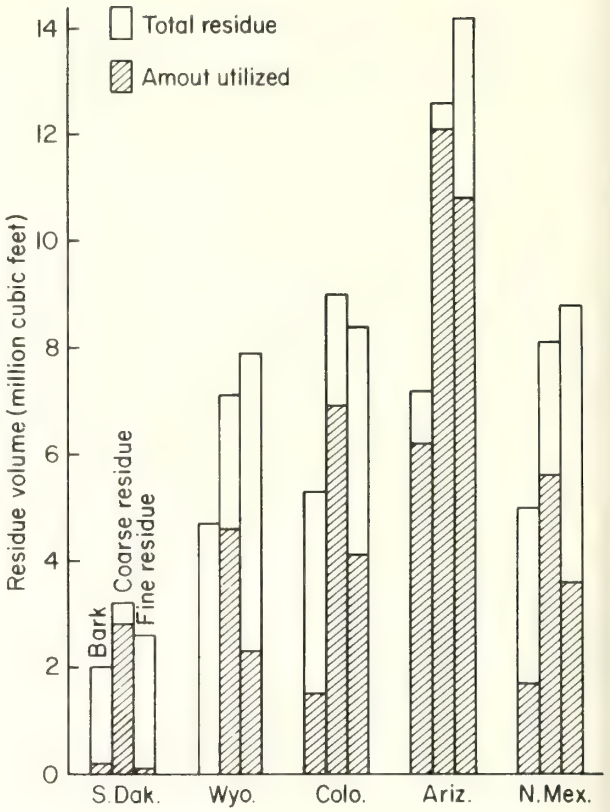


Figure 5.—Mill residues produced and utilized, by type, for each state.

The latest statistics on volume and use of mill residues in the central Rocky Mountains are shown by figure 5. With the exception of Wyoming, these data were collected through questionnaires for the year 1974 by the individual states in cooperation with the Intermountain Forest and Range Experiment Station (Setzer and Barrett 1977a and 1977b, Setzer and Shupe 1977, and Setzer and Throssell 1977). For Wyoming, estimates were from similar information for the year 1969 (Setzer 1971). The proportion of each type of residue that was being used is also shown (fig. 5). A greater proportion of mill residues is being utilized in Arizona than any other state. In all states, coarse residues are utilized to the greatest extent with bark and fine residues utilized in lesser amounts.

Uses being made of mill residues are many and varied. Although there are no data on where these residues are used, the greatest volume is probably used for pulp chips (from the coarse residues). The next largest use is

probably fuel for drying lumber, providing steam power, and heating sawmills. Most mills using wood residues for these purposes incorporate a boiler and steam heat. Two particleboard plants operating in New Mexico use mill residues as raw material. Other plants make a soil amendment from bark and a decorative bark mulch. Other mill residues are used for animal and poultry bedding. Present uses of mill residues for energy include fireplace logs, wood wafers, or briquettes.

What is the energy potential of mill residues that aren't used? Once the cost of harvesting and transporting timber to the mill has been charged to lumber or some other product, the residue becomes a relatively low-cost source of energy. The practicality of utilizing this inexpensive residue for energy rests on economies of scale and the level of unmet local energy demand. The most obvious demand, and one always present, is energy for the mill itself. Sawmills, for example, could be more than energy self-sufficient if all of their residues were used in-house. However, to date, the only move toward energy self-sufficiency by most mills in the central Rocky Mountains is in using residue to generate steam for kiln drying, to operate some machinery, and to heat the mill. Navajo Forest Products Industries in New Mexico has been generating electricity for mill use using mill residues for many years. Managers at two local mills have examined the potential for generating their own electricity but abandoned the idea due to unfavorable economics and problems of selling excess electricity. A recent Canadian study included findings that a mill or group of mills must process 150 million board feet of timber per year for electrical power generation from wood residues to be economically feasible (Canada Department of Environment 1975). However, a study just completed indicated electric energy generation from wood residue should be feasible for a much smaller wood products complex at the Fort Apache Indian Reservation in Arizona.[3] This facility is now being constructed. One central Rocky Mountain electric utility company is burning, on an experimental basis, sawdust mixed with coal.

Several major proposals are pending for additional utilization of mill residue and forest residue. In the Black Hills, several uses of wood for energy have been proposed, including a chemical recovery plant (ethanol), a wood gasification plant with the resulting gas being burned for heat, and a plant for direct firing of wood residue to produce heat or steam. Laramie, Wyo., has been investigated as a possible plant site by a firm which is pioneering a pyrolysis process that recovers gas, oil, and char from organic material. There is also a proposal to use wood residues as an energy source for drying potato waste and alfalfa in Colorado's San Luis Valley.

What, then, is the future for energy from mill residues in the central and southern Rocky Mountains? Mills having boilers for kiln drying or steam power will undoubtedly find this use has top priority for residues. After this allocation, any excess of mill residues should be available to the highest bidder. In many areas pulp chips have been the highest bidder. However, rising shipping costs are making pulp chips a less viable alternative in the Black Hills, Wyoming, and northern Colorado. Partly because of this, it is likely there will be at least one particleboard plant in the Black Hills in the next several years, and possibly one or more elsewhere in the central Rocky Mountains. Particleboard represents a higher economic use for mill residue than energy under most circumstances. There will likely remain substantial volumes of unutilized residues in scattered locations. Perhaps the most promising use of remaining residues is burning for domestic or for industrial heat or steam in conjunction with, or in lieu of, coal. This use may require further processing of the residue, such as hogging, drying, or densifying, depending on the type and location of the installation where the residue is to be used. As with other uses, the practicality of heating with mill residues depends on the cost of hauling the residues from where they are generated to where they are to be burned.

Large Scale Versus Small Scale Energy Use

A major enterprise set up solely for the purpose of producing commercial energy from timber or mill residue would have doubtful economic viability at this time. At this time there is a serious question whether any potential wood-based energy plant could be assured a long-term raw material supply. This is particularly true

[3]*Personal communication with Milton Mater, president, Mater Engineering, Corvallis, Oreg.*

for locations near National Forest lands where RARE II has halted harvesting on a large portion of the region's forests. This situation will be temporary for areas not selected for wilderness status and should be at least partially resolved in 1979. Fragmented ownership and uncertain or undefined management goals pose similar problems in the private sector and timber volumes harvested from these lands have been low in recent years.

More Efficient Harvesting

Improved harvesting methods could possibly make forest residues a more economical energy source than indicated previously (fig. 4). It may be possible to develop new harvesting systems to deliver the whole tree to the woods landing at or below current costs of harvesting bole wood. For example, full tree logging, where trees are felled and then skidded with limbs intact, could be used when the practice is environmentally acceptable. At the landing, trees could be more efficiently processed through a delimber which would also cut the boles into appropriate lengths. This would concentrate branches, tops, and foliage at the landing—essentially without added cost. The cost of chipping at the landing, which would likely have to be done to facilitate handling and transportation, would of course be additional, but brush piling and burning could be eliminated. This kind of situation is represented in figure 6 by the line labeled "Slash-A," which assumes a cost advantage amounting to $0.50 per green ton of slash ($0.55/green metric ton) was produced under the new system where brush disposal was eliminated. "Slash-A" also assumes a chipping cost of $3.50 per green ton ($3.86/green metric ton) at the landing.

Reduced hauling costs could be realized if the residues could be dried or otherwise processed to produce a greater energy content per unit of weight. For example, under assumptions the same as for "Slash-A," but if in addition the residue is dried and/or pelletized so that it can produce 8,000 BTU's per pound (18,608 kj/kg), we have the situation depicted by line "Slash-B." Such additional processing produces cost advantages if distances from the forest to point of use are great. However, complex activities like drying and/or densifying, or even chipping, cannot be carried out in the woods without

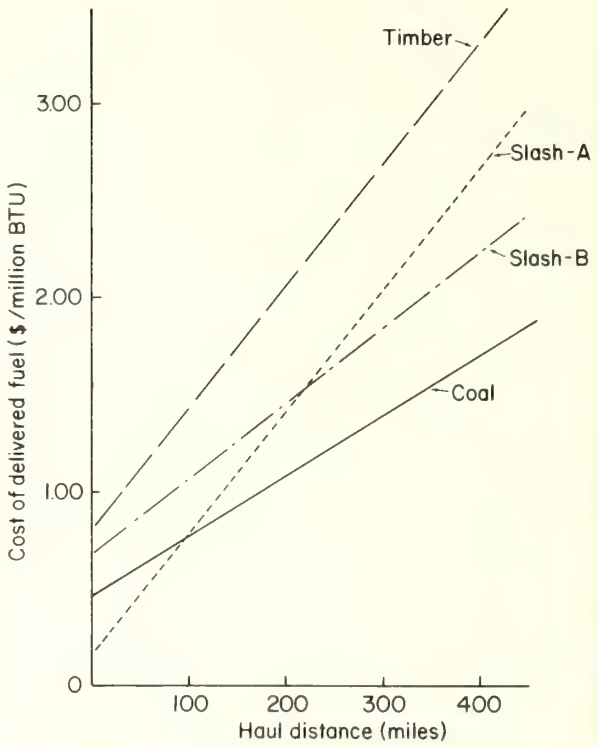


Figure 6.—Cost of energy from timber, coal, and two hypothetical improved harvesting systems by haul distance. (Transportation cost of $0.0625 per ton-mile for all materials)

problems. Very efficient technology and crew management are necessary to carry them out economically.

Despite the less than optimistic outlook for large volume uses of wood for energy in the Rocky Mountains, the outlook is good for selective residential, institutional, commercial, and industrial markets for wood fuel. Fossil fuel price increases could create a ready market for residues and facilitate forest management.

Homes, commercial establishments, and other low-volume energy users, which now use natural or propane gas or fuel oil, may not find switching to coal the most economical alternative. The coal cost estimates shown in figures 4 and 6 will not apply. To reach these users, coal would have to go through one or more wholesalers and incur additional handling costs. This would probably make pelletized wood or cordwood a more attractive alternative than coal, if locally available. However, a barrier to increased use of either wood or coal for heating homes, small commercial establishments, or institutions is lack of installed small-scale equipment for using these fuels. Development of

small-scale equipment that approaches oil or natural gas systems in automation and convenience would increase the demand for wood or coal as oil and natural gas prices increase.

Literature Cited

Baldwin, Pamela, Monte Canfield, Jr., Steven Carhart, et al. 1974. Exploring energy choices: A preliminary report. 81 p. Ford Foundation, Washington, D.C.

Canada Department of Environment. 1975. Combustion technology for the disposal and utilization of wood residue. Can. Dep. Environ. EPS 3-AP-75-4, 92 p. Environ. Protect. Serv., Dep. Environ., Ottawa, Ontario.

Corder, Stanley E. 1973. Wood and bark as a fuel. Sch. For. Res. Bull. 14, 28 p. Oregon State Univ., Corvallis, Oreg.

Dobie, J., and D. M. Wright. 1975. Conversion factors for the forest products industry in western Canada. Can. For. Serv. Inf. Rep. VP-X-97 rev., 92 p. West. For. Prod. Lab., Vancouver, B.C.

Grantham, John B., Eldon M. Estep, John M. Pierovich, Harold Tarkow, and Thomas C. Adams. 1974. Energy and raw material potentials of wood residue in the Pacific Coast states. USDA For. Serv. Gen. Tech. Rep. PNW-18, 37 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Green, Alan W., and Theodore S. Setzer. 1974. The Rocky Mountain timber situation, 1970. USDA For. Serv. Resour. Bull. INT-10, 78 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Hall, E. H. 1976. Comparison of fossil and wood fuels in energy and the wood products industry. Proc. No. P-76-14, 173 p. For. Prod. Res. Soc., Madison, Wis.

Setzer, Theodore S. 1971. Estimates of timber products output and plant residues, Wyoming and western South Dakota, 1969. USDA For. Serv. Res. Note INT-136, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

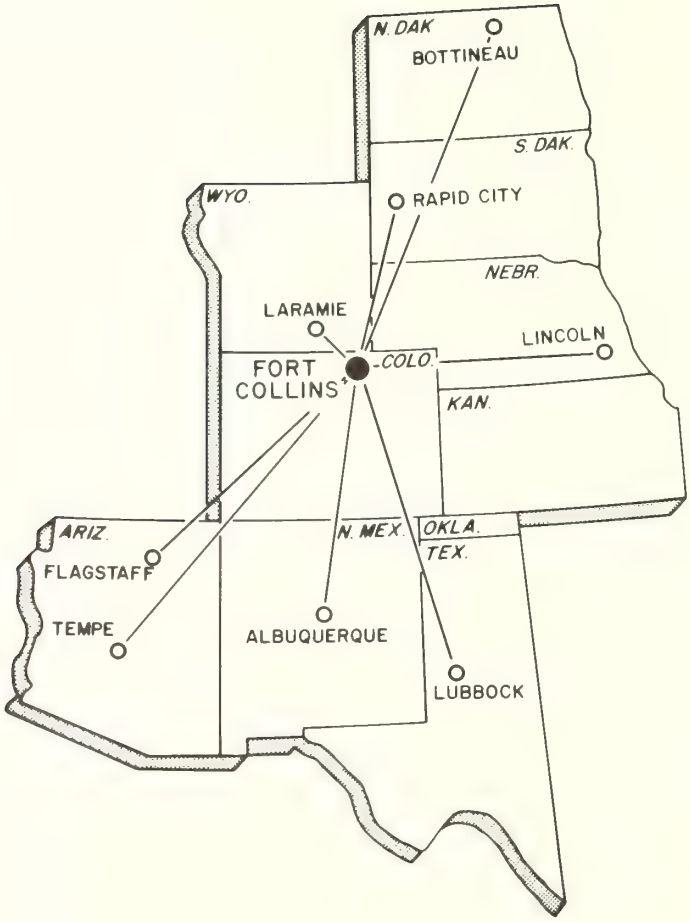
Setzer, Theodore S., and Michael K. Barrett. 1977a. New Mexico timber production and mill residues, 1974. USDA For. Serv. Res. Note INT-231, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Setzer, Theodore S., and Michael K. Barrett. 1977b. Western South Dakota timber production and mill residues, 1974. USDA For. Serv. Res. Note INT-233, 5 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Setzer, Theodore S., and Dorothy G. Shupe. 1977. Colorado timber production and mill residues, 1974. USDA For. Serv. Res. Note INT-232, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Setzer, Theodore S., and Terrence S. Throssell. 1977. Arizona timber production and mill residues, 1974. USDA For. Serv. Res. Note INT-230, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Agriculture — CSU, Fort Collins


N. DAK
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

1979

RESEARCH NOTE RM-369

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of Watering Treatments on Germination, Survival, and Growth of Ponderosa Pine: A Greenhouse Study

Daniel L. Noble, Carleton B. Edminster, and Wayne D. Shepperd[1]

CLEMSON UNIVERSITY LIBRARY
SEP 13 1979
USDA TECH. & AGR. DIV.

Amount and distribution of water from 0.0 to 2.0 inches per month (0.0 to 5.1 cm) affected germination, survival, and growth of ponderosa pine seedlings. Germination was less variable when water was applied once during the month than when water was evenly distributed. Seedling survival and growth was best when seedlings received 1 inch or more of water evenly distributed throughout the month.

Keywords: *Pinus ponderosa*, plant physiology, seed germination

Ponderosa pine (*Pinus ponderosa* Laws.) is the most important pine species in western North America (Harlow and Harrar 1958) and is a major component of the Montane Zone in central Colorado. This zone, at elevations from about 6,500 to 9,400 feet (1,970-2,850 m), is the first forested belt above the plains on the east side of the Colorado Rockies (Miller and Choate 1964). Altitude limits vary locally with latitude, aspect, and soil depth.

Ponderosa pine forests are important for timber, forage, water, esthetics, recreation, and wildlife habitat. Successful regeneration following disturbances is critical to the silviculture and management of these forests.

[1]*Ecologist, Mensurationist, and Associate Silviculturist, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Although successful regeneration of these forests may be possible (Myers 1974, Pearson 1950), more information is needed on the effects of environmental factors on natural regeneration.

According to Pearson (1950) amount and distribution of precipitation during the growing season are major factors influencing regeneration success. Hayes (1965) also concluded that inadequate moisture is a common obstacle to regeneration east of the Sierra-Cascades. The time needed for germination and subsequent establishment of ponderosa pine seedlings has been observed to vary with precipitation conditions, both in central Colorado (Myers 1974) and in the southwest (Schubert et al. 1970).

The studies reported here concern the effects of amount and distribution of precipitation

during the growing season on ponderosa pine regeneration success and were made under controlled greenhouse conditions to supplement field observations. Germination, initial survival, and early growth of seedlings were compared under watering treatments selected to represent precipitation patterns likely to occur on the Manitou Experimental Forest in central Colorado.[2]

Methods and Materials

Seed Source

The seed used was western ponderosa pine seed, collected in 1974 from the San Isabel National Forest, Hayden Creek drainage, at an elevation of 8,000 feet (2,438 m). The seed had been stored at 4° C. Average laboratory germination prior to the study was 68%.

Soil and Seedling

Forest soil from 7,800 feet (2,377 m) elevation on the Manitou Experimental Forest was used. It is a coarse sandy-loam developed from Pikes Peak granite and covers much of the Experimental Forest (Marcus 1973, Retzer[3]). Moisture holding capacities at 1/3 and 15 bars, determined in the laboratory, were approximately 24 and 13%, respectively. The soil was screened through 4-mesh hardware cloth, thoroughly mixed, placed in pots, 7 inches (18 cm) deep and 6 inches (15 cm) in diameter, and soaked to saturation twice daily for 3 days. Twenty seeds were then sown on the surface of the soil in each pot. All pots were again soaked to insure soil moisture near saturation before watering treatments were begun. A total of 150 pots were prepared.

[2]USDA Forest Service weather records for a 35-year period (1941-75) from the Manitou Experimental Forest, Colorado (records on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.) indicate that average precipitation for the months May and June (critical months for germination and initial seedling establishment) is 1.90 and 1.65 inches (4.8 and 4.2 cm), respectively. Precipitation for these months, generally ranging from 0.14 to 5.05 inches (0.4 to 12.9 cm) per month, is most likely to fall in either several small storms of 0.25 inch (0.6 cm) or less, or in one or two larger storms.

[3]Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. 18 p. (Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.).

Experimental Design and Treatments

The study consisted of two experiments. Pots received 0.0, 0.5, 1.0, 1.5, or 2.0 inches (0.0, 1.3, 2.5, 3.8, or 5.1 cm) of water monthly. In experiment A the water was evenly distributed throughout the month in applications of 0.25 inch (0.64 cm). In experiment B pots received the assigned monthly level of water in one aplication. Each experiment was arranged in a randomized block design with 15 replications.

Greenhouse Environment

The environment in the greenhouse at Fort Collins, Colo., was maintained as close as possible to average field conditions during the growing season on the Manitou Experimental Forest. Air temperatures were 70° F (21° C) day and 40° F (4° C) night. The photoperiod was 16 hours of natural and artifical light. The transition period of temperature changes coincided with photoperiod. Relative humidity was varied from 20-30% (day) to 70-80% (night). However, high light intensities—up to 12,000 footcandles (129,000 lx)—associated with openings in forest cover on the Manitou Experimental Forest could not be reached in the greenhouse. The normally lower light intensity at 5,000 feet (1,524 m) elevation was further reduced by the greenhouse glass, so that light intensity varied from 3,000 footcandles on cloudy days to about 5,000 footcandles on clear days.

Measurements and Analyses

Number of germinating seeds, number of surviving seedlings, and cause of mortality were recorded twice weekly. At the end of 20 weeks soil was carefully washed from the roots of all live seedlings and the top height and root length measured to the nearest millimeter. Seedlings were oven dried for 24 hours at 100° C and weighed to the closest 0.1 mg.

Germination and survival were expressed as a percent of the number of seeds sown per pot; top height, root length, and total seedling dry weights were means of all surviving seedlings in a pot. Differences due to treatments were tested for significance by analyses of variance with arc sine transformations for percentage data. Tukey's method of simultaneous con-

fidence intervals was used to determine which treatment differences were significant (Graybill 1976).

Results

Germination

Average germination under the treatments where water was evenly distributed ranged from 26% for the 0.0 water to 46% for 2.0 inches of water. Although significant differences in germination occurred between watering treatments in this experiment, definite trend was not observed (fig. 1). Likewise, where water was applied once a month (experiment B), germination was not significantly affected by amount, varying only from 27% at the 0.5 inch per month to 31% at the 1.5 inches per month. Germination for the 0.0 and 2.0 inch levels was 29% (fig. 1).

Length of Germination Period

The length of time over which seedlings emerged was affected little by either the distribution or amount of water received. In both experiments germination began in about 14 days and was generally completed 49 days after sowing. In experiment B some delayed germination occurred following the third application of water (fig. 2).

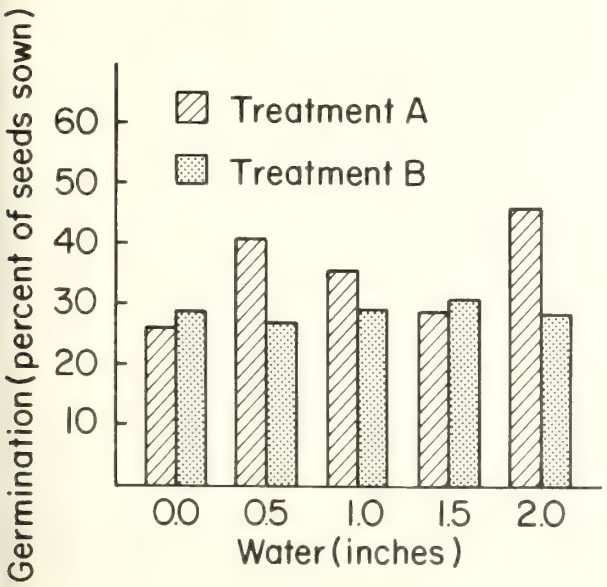


Figure 1.—Total germination in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Seedling Survival

Number of seedlings surviving after 20 weeks was related to both amount and distribution of water. When water was evenly distributed, 1.0 inch or more of water was required to sustain significant survival ($0.05 < \alpha \leq 0.10$). Survival varied from 14% at 0.5 inch per month to 43% at 2.0 inches per month (fig. 3) in this experiment. When water was applied once a month, survival percentages at all water levels were low and were not significantly different, only varying 16-20% (fig. 3).

Causes of Mortality

In experiment A drought was the principal cause of mortality at all levels of watering (table 1). Damping-off was an important cause of mortality at 1.5 inches or more. At the higher water levels (1.0 in or more), losses also occurred from failure to establish. The radicle emerged from the seedcoat and did not develop further, either because the seeds could not imbibe sufficient water for the radicle to penetrate the soil or seeds did not have enough germination vigor to complete establishment.

In experiment B drought was the major cause of mortality at all treatment levels (table 1). Seedling losses from damping-off were minor even at 1.5 and 2.0 inches. However, mortality from failure to establish was important at 1.0 inch or more of water.

Seedling Growth

Seedling biomass, top height, and root elongation were not significantly related to amount of water in either experiment. In experiment A plant growth data for 0.5 inch were not analyzed because of poor survival.

Because the two water distribution methods were separate experiments, seedling growth could not be compared statistically. However, there are apparent differences, since seedlings from the evenly distributed watering experiment were considerably heavier and had slightly longer tops and roots than seedlings watered once a month (table 2).

Discussion and Conclusion

The greenhouse environment was more favorable to germination, survival, and growth than are natural conditions. It is difficult, therefore, to extrapolate results from the greenhouse to the field. Nevertheless, certain inferences can be drawn from these experiments concerning the effects of amount and distribution of precipitation on natural regeneration of ponderosa pine in the central and southern Rocky Mountains.

Assuming adequate seed is available, along with favorable seedbed conditions, only slightly more seedlings emerge with frequent showers than with one or two larger storms. When soils are initially saturated, the amount of subsequent precipitation has no clear effect on germination, regardless of rainfall frequency (fig. 1). Most germination is completed in 49 days whether precipitation is well distributed or occurs in only one or two storms (fig. 2).

Seedling survival is strongly affected by both distribution and amount of precipitation. At least 1 inch of evenly distributed precipitation is needed monthly before seedling survival could be considered adequate and additional rainfall may further increase survival. Conversely, seedling survival is inadequate with infrequent precipitation even at 2 inches per month (fig. 3).

The distribution of precipitation can affect seedling growth. Seedlings receiving 1.0 or more inches of well distributed precipitation per month were consistently heavier, taller, and had longer roots than seedlings receiving the same amount of rainfall once per month (table 2). However, the magnitude of seedling growth in the greenhouse may not be comparable to field-grown seedlings. Average top height was about the same as that found by Jones (1971) for field grown first-season seedlings but root length was about 1-1/3 times greater.

In this study only precipitation has been considered. Regeneration success is affected by many environmental factors and their interactions, which must be evaluated before the effectiveness of a single factor such as precipitation can be fully analyzed. It is apparent, however, the amount and distribution of precipitation can be a major factor in the establishment of ponderosa pine seedlings.

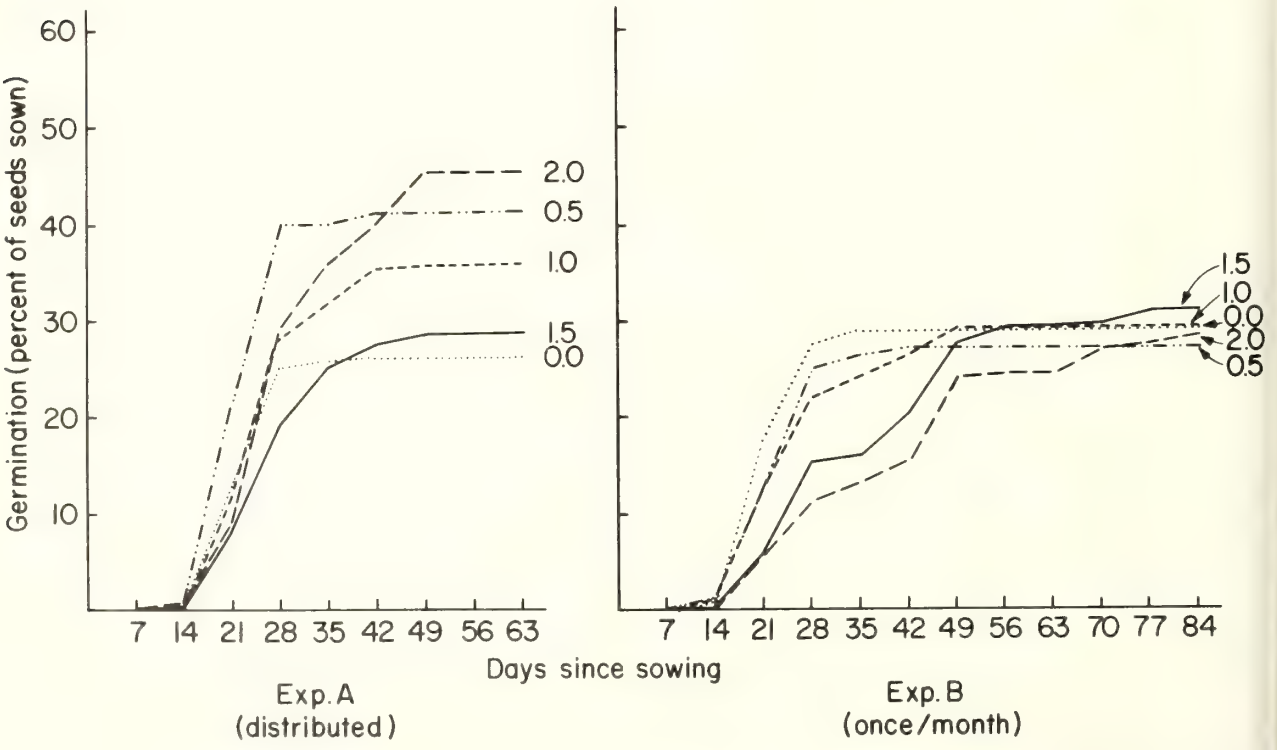


Figure 2.—Length of germination period in relation to water amounts and distribution.

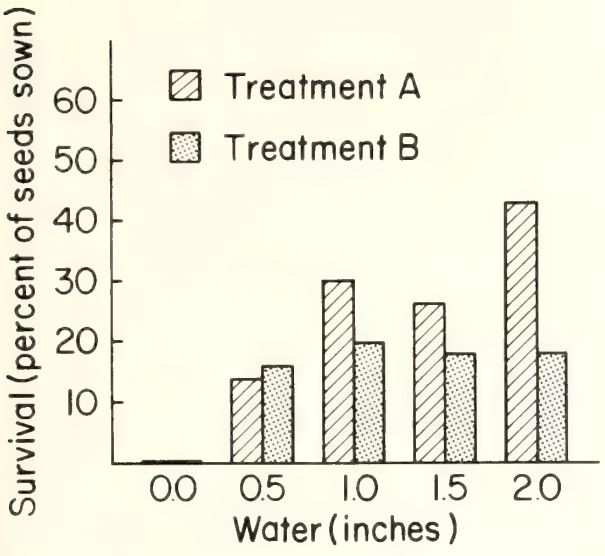


Figure 3.—Seedling survival after 20 weeks in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Literature Cited

Graybill, Franklin A. 1976. Theory and application of the linear model. 704 p. Duxbury Press, North Scituate, Mass.

Harlow, W. M., and E. S. Harrar. 1958. Textbook of dendrology. McGraw-Hill Inc. N.Y. 561 p.

Hayes, G. Lloyd. 1965. Providing for optimum regeneration in the logging plan—east side. West. Refer. Coord. Comm. [Vancouver, B.C., Dec. 1965] Proc. 1965:6-9. West. For. Conserv. Assoc., Portland, Oreg.

Jones, John R. 1971. Mixed conifer seedling growth in eastern Arizona. U.S. For. Serv. Res. Pap. RM-77, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Marcus, Steven R. 1973. Geology of the Montane Zone of central Colorado—with emphasis on Manitou Park. USDA For. Serv. Res. Pap. RM-113, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Table 1.—Percent total mortality, by cause, of greenhouse-sown ponderosa pine seedlings (A) watered at predetermined intervals during the month, and (B) watered once a month

Monthly amount of water		Drought		Damping-off		Failure to establish		Other causes	
		A	B	A	B	A	B	A	B
(in)	*(cm)*								
0.0	0.0	98.7	95.4	0.0	0.0	1.3	4.6	0.0	0.0
0.5	1.3	96.1	93.5	1.3	0.0	2.6	6.5	0.0	0.0
1.0	2.5	62.5	58.6	0.0	0.0	18.8	37.9	18.7	3.5
1.5	3.8	42.8	75.6	28.6	4.9	14.3	19.5	14.3	0.0
2.0	5.1	60.0	80.6	30.0	6.5	10.0	12.9	0.0	0.0
Average		90.3	84.5	3.2	1.8	4.3	13.2	2.2	0.5

Table 2.—Average growth of greenhouse-grown ponderosa pine seedlings (A) watered at predetermined intervals, and (B) watered once a month. (Means were statistically homogeneous at $\alpha = 0.05$)

Monthly amount of water		Dry weight		Seedling height		Root length		Root/shoot ratio	
		A	B	A	B	A	B	A	B
in	*cm*	*mg*		*mm*		*mm*			
[1]0.5	1.3	(41.1)	63.9	(42.8)	46.8	(154.7)	162.8	(3.64)	3.51
1.0	2.5	104.4	87.7	52.2	51.4	184.8	178.5	3.53	3.46
1.5	3.8	147.8	88.0	53.2	49.2	196.0	189.2	3.73	3.85
2.0	5.1	142.0	84.5	53.6	49.2	180.4	174.2	3.38	3.53
Average		114.4	81.2	51.1	49.2	180.8	176.2	3.56	3.59

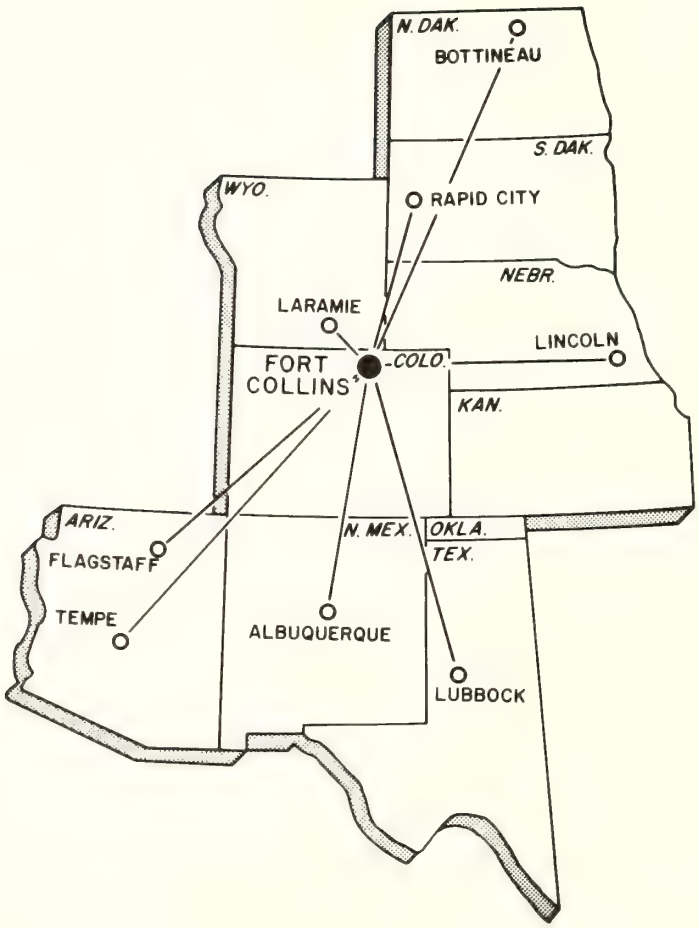
[1]*In experiment A survival at the 0.5 inch water level was inadequate for analysis; data are included for general information.*

Miller, Robert L., and Grover A. Choate. 1964. The forest resource of Colorado. USDA For. Serv. Resour. Bull. INT-3, 54 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Myers, Clifford A. 1974. Multipurpose silviculture in ponderosa pine stands of the Montane Zone of central Colorado. USDA For. Serv. Res. Pap. RM-132, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pearson, G. A. 1950. Management of ponderosa pine in the southwest. USDA For. Serv. Agric. Monog. No. 6, 218 p.

Schubert, Gilbert H., L. J. Heidmann, and M. M. Larson. 1970 Artificial reforestation practices for the southwest. USDA For. Serv. Agric. Handb. 370, 25 p.


N. DAK.
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

1979

RESEARCH NOTE RM-370

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Long-term Changes in Cottonwoods on a Grazed and an Ungrazed Plains Bottomland in Northeastern Colorado[1]

CLEMSON UNIVERSITY LIBRARY
SEP 13 1979
SCI., TECH. & AGR. DIV.

Glenn L. Crouch[2]

Numbers of cottonwood trees declined between 1961 and 1978 on a grazed and an ungrazed bottomland in northeast Colorado. Cottonwoods were larger in diameter in 1978, but basal area stocking was unchanged. Trees were taller in 1978 on the ungrazed area, and amounts of canopy deadwood were greater on both areas. Water management, grazing by livestock and deer, plant competition on the ungrazed area, and beaver-felling of young trees all contributed to a lack of regeneration that appears responsible for the general decline in overstory vegetation.

Cottonwood bottomlands are unique habitats in the shortgrass plains of eastern Colorado. They provide almost the only native tree cover and are inhabited by many species of wildlife. Bottomlands also provide livestock pastures that are protected from the severe winter weather so common on the Plains.

Albertson and Weaver (1954) found that the number of native woody species decreased westward from the Mississippi River. Pioneer tree types, such as cottonwood (*Populus* spp.), willow (*Salix* spp.), elm (*Ulmus* spp.), and boxelder (*Acer negundo*), extend furthest west, but only along water courses. Along the South Platte River, in northeastern Colorado, cottonwoods (P. *deltoides* var. *occidentialis*) and willows (S. *amygdaloides*) are virtually the only trees remaining from the large number of species found further east.

Aboreal vegetation was apparently sparse in the last century compared to today along the South Platte River (Conklin 1978, Fremont 1956, Fuller and Hafen 1957, Ware 1911, Williams 1976).

Large-scale ranching began in the late 1860's. During most of the year, cattle were scattered on upland ranges, but in winter they would move to native hay meadows along the river. Irrigated farming began in the early 1860's using water diverted from the river, but large-scale operations did not begin until later in the 19th century. Land-use patterns are similar today.

By the late 1950's, cottonwoods of various sizes were relatively abundant over most of the South Platte bottomlands. In mid-summer, some seedlings were present on moist sandbars and along the edges of recently inundated channels. Older trees up to 1 foot d.b.h. occurred in fairly dense groves, usually along dormant

[1]*The research reported from 1961 was conducted while the author was with the Colorado Cooperative Wildlife Research Unit, Colorado State University, and the Colorado Game and Fish Department. The work in 1978 was conducted at the Rocky Mountain Forest and Range Experiment Station.*

[2]*Principal Research Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

channels, while the largest individuals, up to 30 inches d.b.h., were widely scattered and usually considerably distant from the river channels. Willows were fewer in number, but similarly distributed.

The Study

Cottonwood on two tracts of bottomland along the river between the towns of Crook and Iliff, Colorado, were studied from 1959 to 1961 to determine effects of grazing on wildlife habitat (Crouch 1961). In this area, the bottomland plant community averaged about one-half mile in width, and the main river channels meandered within the belt. One of the 2-linear-mile tracts was owned by the Colorado Game and Fish Department (now Colorado Division of Wildlife) and had been protected from grazing for about 7 years. The second tract, privately-owned, was located about 10 miles upstream. It was subjected to several grazing regimes, with cattle present all year on some portions, and seasonally on others. Data were collected again in 1978 from the same study transects. The results derive therefore, from bottomland protected from grazing for 8 and 25 years, and from a similar area grazed continuously during that time.

Methods

Cottonwoods were inventoried along 10 baselines, spaced one-fifth mile apart, extending across the bottomlands on each study area. In winter 1960-61, three permanently marked sampling points were randomly spaced along each transect on the ungrazed tract, and similar points were temporarily established on the grazed area. Each point served as the center of a 0.1-acre circular sampling plot on which trees were counted, and the d.b.h. and height of each tree was determined. Estimates were also made of percentages of live wood in the tree crowns as a measure of relative vitality.

In spring 1978, most of the permanent plots on the ungrazed area were located and remeasured. On the grazed tract, sampling plots were again randomly spaced and measured along transects reestablished close to those utilized in 1961.

Data were analyzed by t-tests at P = 0.05. Data from 1961 and 1978 were compared for the various attributes evaluated on each study area.

Results

Numbers and characteristics of cottonwoods measured in 1961 were similar on both study areas (table 1). Cottonwoods were widely distributed (63% of plots occupied), and frequencies were the same on the ungrazed and grazed tracts. Relative vitality of cottonwoods was also similar between areas.

By 1978, numbers of cottonwoods had declined by 33% on the ungrazed and 53% on the grazed area (table 1). The trees were larger in diameter in 1978 than in 1961, and partition into 5-inch-diameter classes showed a dramatic shift to larger individuals (fig. 1). Basal area stocking was not significantly different between years on either area. Although fewer trees were counted, those present were larger in diameter than in 1961. Cottonwoods were significantly taller in 1978 than in 1961 on the ungrazed area, but not on the grazed tract. Relative vitality of cottonwoods also declined between the two measurements on both areas.

Table 1.—Characteristics of cottonwoods in 1961 and 1978 on a grazed and an ungrazed bottomland in northeast Colorado

	Grazed		Ungrazed	
	1961	1978	1961	1978
Number/acre	38.3	[1]17.6	47.7	[1]32.0
D.b.h. (*inches*)	8.9	[1]13.4	8.6	[1]12.8
Height (*feet*)	29.9	31.8	27.1	[1]35.4
Basal area/acre, (*square feet*)	25.8	21.1	28.9	33.4
Live crown, (*percent*)	70.1	[1]48.2	72.1	[1]55.8

[1]*Year values within this category and grazing class are significantly different (P = 0.05).*

Discussion

Conditions for tree growth in the bottomlands probably began to improve about 1900, when irrigation projects somewhat stabilized the flow of water in the river, and provided a year-round surface and shallow subsurface flow. Gradual

reduction in livestock grazing and changes in their season of use probably also contributed to the relatively high number of trees observed in 1961. Heavy grazing has long been recognized as a detriment to the reproduction of cottonwoods and other bottomland hardwood trees (Kellogg 1905, Putnam 1951).

Although no data are available, it seems reasonable to assume that numbers of trees reached a high point in the 1950's and declined since then. Moreover, current evidence points to a continued decline in numbers on both study areas, if the same environmental conditions persist that have occurred between 1961 and 1978. Data from the few cottonwoods cored and aged in 1978 indicated that trees greater than or equal to 12 inches d.b.h. were more than 50 years old. More than 50% of the cottonwoods on the ungrazed tract and 60 percent of those counted on the grazed area were in this diameter class (fig. 1). Five trees, ranging from 7 to 10 inches d.b.h., were estimated to be 30 to 40 years old.

Several causes appear plausible to explain the decline in cottonwoods. Completion of their life-cycles has removed many of the older trees, but mortality has been lowest within this class. Insects and disease may also be the important reasons, but no evidence was observed to support them as major causes. Beavers account for removal of many of the smaller trees. Lowering of water tables, believed responsible for cottonwood mortality elsewhere on the Plains, did not occur, according to long-term records from wells adjacent to the study areas (Hurr et al. 1975, Major et al. 1975). Mechanical restructuring of the main channel after floods in the 1960's removed some trees from the ungrazed tract. Browsing by livestock on the grazed area and by increasing numbers of deer on both areas also probably restrained cottonwood reproduction. Competition from the protected understory vegetation may have limited regeneration on the ungrazed tract. Among all possibilities, the most important factor appears to be water management.

Barclay (1924) and Putnam (1951) stated that cottonwood seed requires bare, moist, mineral soil for germination. Such sites were uncommon on the ungrazed tract during the spring and early summer of the earlier study period, and presumably in most years since protection. Herbaceous growth began in early spring, and on the ungrazed tract, grasses and forbs soon covered nearly all areas not already occupied by woody vegetation. By early summer, when cottonwoods were disseminating seed, herbs

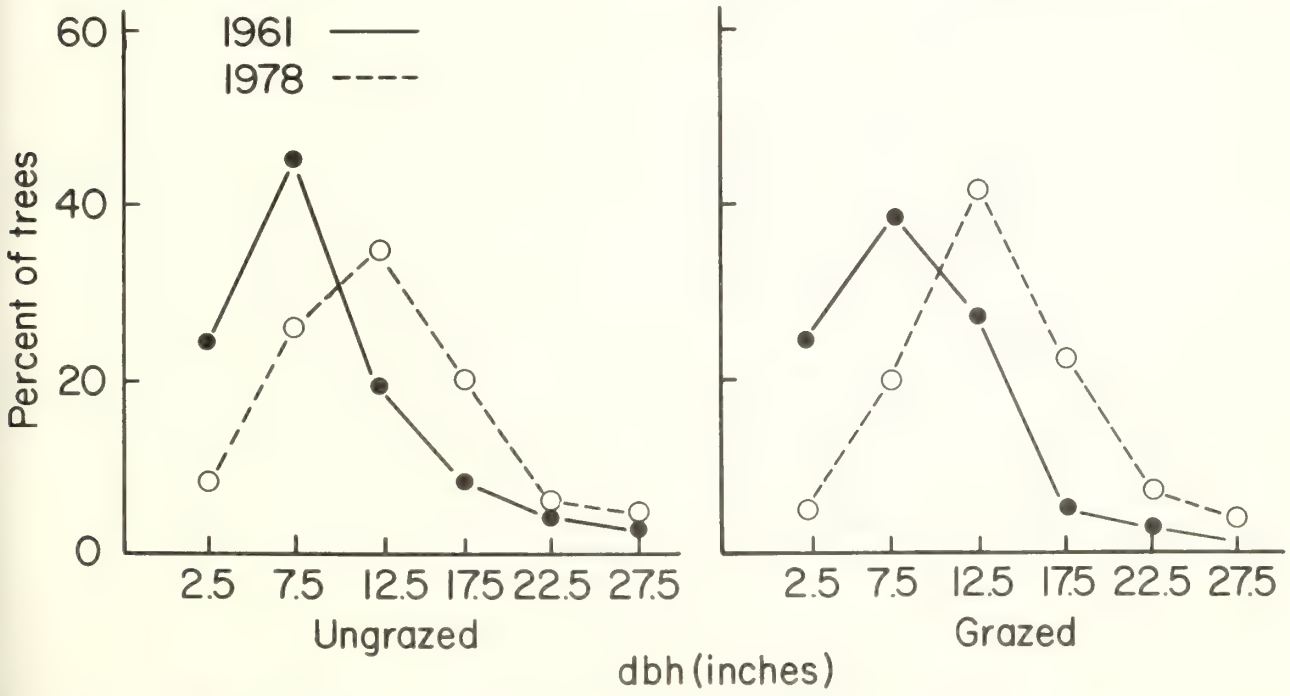


Figure 1.—Diameter class distribution of cottonwood trees in 1961 and 1978 on a grazed and an ungrazed bottomland in northeastern Colorado.

had reached heights of 1 to 3 feet. The only available sites for cottonwood germination on the ungrazed bottomland were in the channels themselves where water levels did not begin to recede until late June. Actually, in 1960 and 1961, there was an abrupt decline in river flow in mid-June when the water level dropped about 2 feet in a few days because of irrigation demand. This decrease bared most of the channel bed, which dried out almost immediately because of its sandy-gravelly texture. It was only on the margins of the permanently flowing main channels, or around small pools cut off from main channels that seedlings were found; by late September these were once again submerged by the increased flow of post-irrigation water.

The grazed area offered a more suitable habitat for the germination and establishment of trees. The main channels were wider, partially because of less plant cover to retard erosion, and minor reductions in volumes of water flow caused extensive areas of potential seedbeds to be exposed. However, the large numbers of cattle present during the spring and early summer consumed virtually all of the seedlings that sprouted.

All of these factors probably contributed to the lack of regeneration that seems largely responsible for the general decline in cottonwoods on both areas. Moreover, it is likely that numbers of trees will continue to decline if (1) upstream controls on riverflow are effective in preventing overbank flooding during seed dissemination, (2) understory vegetation remains totally protected from livestock grazing and fire on the ungrazed area, (3) heavy livestock use continues on the grazed tract, and (4) predation by beavers continues at the current rate.

Literature Cited

Albertson, F. W., and J. E. Weaver. 1945. Injury and death or recovery of trees in prairie climate. Ecol. Monogr. 15(4):393-434.

Barclay, H. 1924. The plant succession of the floodplain of the Mississippi River, with special reference to the pioneer stage. M. A. Thesis, Univ. Minn. 102 p.

Conklin, E. B. 1924. A brief history of Logan County, Colorado. Welch-Haffner Co., Denver, Colo. 354 p.

Crouch, G. L. 1961. Wildlife populations and habitat conditions on grazed and ungrazed bottomlands in Logan County, Colorado. M. S. Thesis, Colo. State Univ., Fort Collins. 144 p.

Fremont, J. C. 1956. Narratives of exploration and adventure. (A. Nevins, ed.) Longmans, Green, and Co., New York. 532 p.

Fuller, H. M., and L. R. Hafen (eds.). 1957. The journal of Captain John Bell. Arthur H. Clark Co., Glendale, Calif. 349 p.

Hurr, T. R., P. A. Schneider, Jr., and D. R. Minges. 1975. Hydrology of the South Platte River Valley, northeastern Colorado. Colo. Water Resour. Circ. 28. 24 p. U.S. Geol. Surv. and Colo. Water Conserv. Board, Denver.

Kellogg, R. S. 1905. Forest belts of western Kansas and Nebraska. USDA For. Serv. Bull. 66. 44 p. Washington, D. C.

Major, T. J., L. Kerbs, and R. D. Penley. 1975. Water-level records for Colorado 1971-75. Colo. Water Resour. Basic-Data Release 37. 356 p. U.S. Geol. Surv. and Colo. Water Conserv. Board, Denver.

Putnam, J. A. 1951. Management of bottomland hardwoods. U.S. Dep. Agric., For. Serv., South. For. Exp. Stn., Occas. Pap. 116, 60 p. New Orleans, La.

Ware, E. R. 1911. The Indian war of 1864. Crane and Co., Topeka, Kans. 601 p.

Williams, G. P. 1978. Historical perspective of the Platte Rivers in Nebraska and Colorado. p. 11-41. *In* Proc. Lowland River and Stream Habitat in Colo. Symp. [Oct. 4-5, 1978, Greely, Colo.]

979

RESEARCH NOTE RM-371

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Eastern Redcedar Seed Sources Recommended for North Dakota Sites

James L. Van Deusen[1]

CLEMSON UNIVERSITY LIBRARY
SEP 13 1979
SCI., TECH. & AGR. DIV.

Abstract

A North Dakota study of 12 eastern redcedar (*Juniperus virginiana* L.) seed sources indicates that seed from planted stands near Anselmo, Custer County, Nebr.; from a shelterbelt at Towner, N. Dak.; and from native stands in western Wisconsin and western Minnesota can be recommended for most North Dakota sites.

Management Implications

Survival and subsequent height growth of trees from four, and perhaps five, seed sources has been good enough to make it worthwhile for land managers and tree planters to request stock from those provenances.

Seed sources from Custer County, Nebraska (2810), western Wisconsin (2806), a planted shelterbelt at Towner, N.Dak. (2809), and western Minnesota (2808), are adapted to sites similar to the Denbigh Experimental Forest. Survival of trees from these sources has been good. Because height growth has been so affected by browsing, it is not possible to know how well the trees would have grown under conditions of less deer pressure; but, juniper stock from these four sources can be recommended for most North Dakota planting sites.

A fifth source, Nebraska 3211, may also be worth strong consideration for North Dakota plantings. Once established, these trees grew as well as trees from three of the four recommended sources.

More definitive site-seed source recommendations will be possible later from a cooperative regional study of eastern redcedar and Rocky Mountain juniper seed sources. However, seedlings from that study are still in nursery beds. The regional juniper test may identify several seed sources that are better than the ones recommended from this test, but results from the regional test are still many years away.

Introduction

In the northern Great Plains, where only a few local areas have native trees, protection from the characteristic climatic extremes can best be provided by introduced, adapted tree species.

Hardy trees with year-round foliage are in demand for environmental enhancement plantings in the northern Great Plains. In addition to being evergreen, conifers have another advantage over deciduous trees in that

[1]*Research Forester, Rocky Mountain Forest and Range Experiment Station, located at the Station's research work unit at Bottineau, in cooperation with North Dakota State University. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

once the crown is groomed to meet a user's goals, little or no additional crown treatment is needed.

Eastern redcedar (*Juniperus virginiana* L.) has proved adapted to many planting situations in the Great Plains (George 1953, Read 1958), but seed sources have not been delineated that will provide uniformly fast growing, hardy, well formed trees for planting in the northern Great Plains.

The native range of eastern redcedar in North Dakota is an isolated occurrence in two southwestern counties, Billings and Grant. Native Rocky Mountain juniper (*Juniperus scopulorum*), on the other hand, is found in scattered locations in the western third of North Dakota (Fowells 1965). Van Haverbeke (1968) found *Juniperus* populations in North Dakota were strongly influenced by the parental type *J. scopulorum*. In fact, the *Juniperus* stands in the whole Missouri River Basin region may be of hybrid origin. Those in the northwest half of the Basin were influenced more by the Rocky Mountain juniper parental type, while stands in the southeastern half exhibited greater influence by the eastern redcedar parental type.

Tree characteristics often vary according to seed source. Growth, survival, and winter foliage color frequently are influenced strongly by provenance in junipers. Cedar-apple rust (*Gymnosporangium juniperi-virginianae*) is sometimes so debilitating to apple trees that apples cannot be grown near junipers.

This study was installed as part of the continuing search for suitable species to meet environmental planting needs for the region. It was begun as a cooperative test of eastern redcedar with the former Central States Forest Experiment Station. This was the only test from that study made in a northern Great Plains climate.

The Study

The Denbigh Experimental Forest is a 640 acre block of land in McHenry County. Soils at Denbigh and in the surrounding area are nearly pure sand. On the Experimental Forest water is abundant in most years within 6 feet of ground surface. Before tree planting began at Denbigh in the early 1930's, the topography was sandy dunes with native range grasses and forbs as a sparse ground cover. The area was locally known as the Denbigh Dunes. Now, the soils have been stabilized by tree plantations of many species and seed sources.

Forty 2-0 seedlings from each of 12 eastern redcedar sources were hand planted in spring 1964 at 2.1 m^2 spacing on the Experimental Forest.

To identify variations that might be associated with seed sources, periodic measurements and observations were made on test trees. Survival, total height, winter foliage color, animal damage, and presence of cedar-apple rust were measured or evaluated at various times during the 13-year test.

Geographic distribution of the sources is shown in figure 1. Sources of the test seedlings are shown in the following tabulation:

Lake States Exp. Stn.[2] no.	Geographic source and location received from
3206-N-64	Buffalo County, Wis. Cent. States For. Exp. Stn.[2] (#9)
3207-N-64	Mason County, W. Va. Cent. States For. Exp. Stn. (#10)
3208-N-64	Montgomery County, Ark. Cent. States For. Exp. Stn. (#11)
3209-N-64	Trego County, Kans. Cent. States For. Exp. Stn. (#14)
3210-N-64	Madison County, Ky. Cent. States For. Exp. Stn. (#16)
3211-N-64	Seward County, Nebr. Cent. States For. Exp. Stn. (#20)
2805-N-64	Platte River, Nebr. Plumfield Nursery, Fremont, Nebr.
2806-N-64	Western Wis. Lake City Nursery, Lake City, Minn.
2807-N-64	Crescent, Okla. Oklahoma Dep. of Agric.
2808-N-64	Western Minn. Towner Nursery, Towner, N. Dak.
2809-N-64	Unknown (Planted shelterbelt) Towner Nursery, Towner, N. Dak.
2810-N-64	Unknown (Stands near Anselmo, Custer County, Nebr. USDA For. Serv., Halsey, Nebr.

[2]*The Lake States and Central States Forest Experimen Stations have been combined into the North Central Fores Experiment Station.*

Trees from seed sources 2809 and 2810 were grown at the Towner, N. Dak. nursery. Otherwise, the stock from sources 2805 through 2810 were raised at different nurseries. Trees from sources 3203 through 3211 all were grown at the George White State Nursery, Licking, Mo.

Trees from the George White Nursery were frozen in transit from their Missouri shipping point to North Dakota. Also they dried out somewhat during the cold (4° C) storage period between delivery and planting.

The plantation consists of 10 replications of 4-tree plots. The planting site was plowed in 1963, then cultivated and disked prior to planting. The site was sod- and weed-free at planting time. Seedlings that died were replaced in spring 1965 from line-out beds at the Towner, N. Dak. nursery with seedlings of appropriate sources.

Grass and forb competition was minimized in the first year by repeated cultivation between rows and between trees within rows. Thereafter, the plantation was cultivated once annually through 1969. No cultural treatments were applied after 1969.

Results and Discussion

Survival and Growth

Seedlings from central Nebraska (2810) survived best and were tallest of all sources (table 1). The survival and height growth of all sources, however, may have been influenced by pre- and post-planting conditions. Since trees from sources 2805 through 2810 were raised at different nurseries, their early performance could be confounded by nursery effects. By 1976, any early nursery effects should have disappeared.

The Seward County, Nebraska source (3211) has kept up height growth along with the rest of the best ranking sources. Its survival has been low; but, perhaps because of freezing and drying before planting, only a dozen really vigorous trees were planted.

Survival of Nebraska sources 2805 and 3211 may have been low in the beginning because of poor tree vigor at planting time. Neither of those sources has had much mortality since 1967 (table 1).

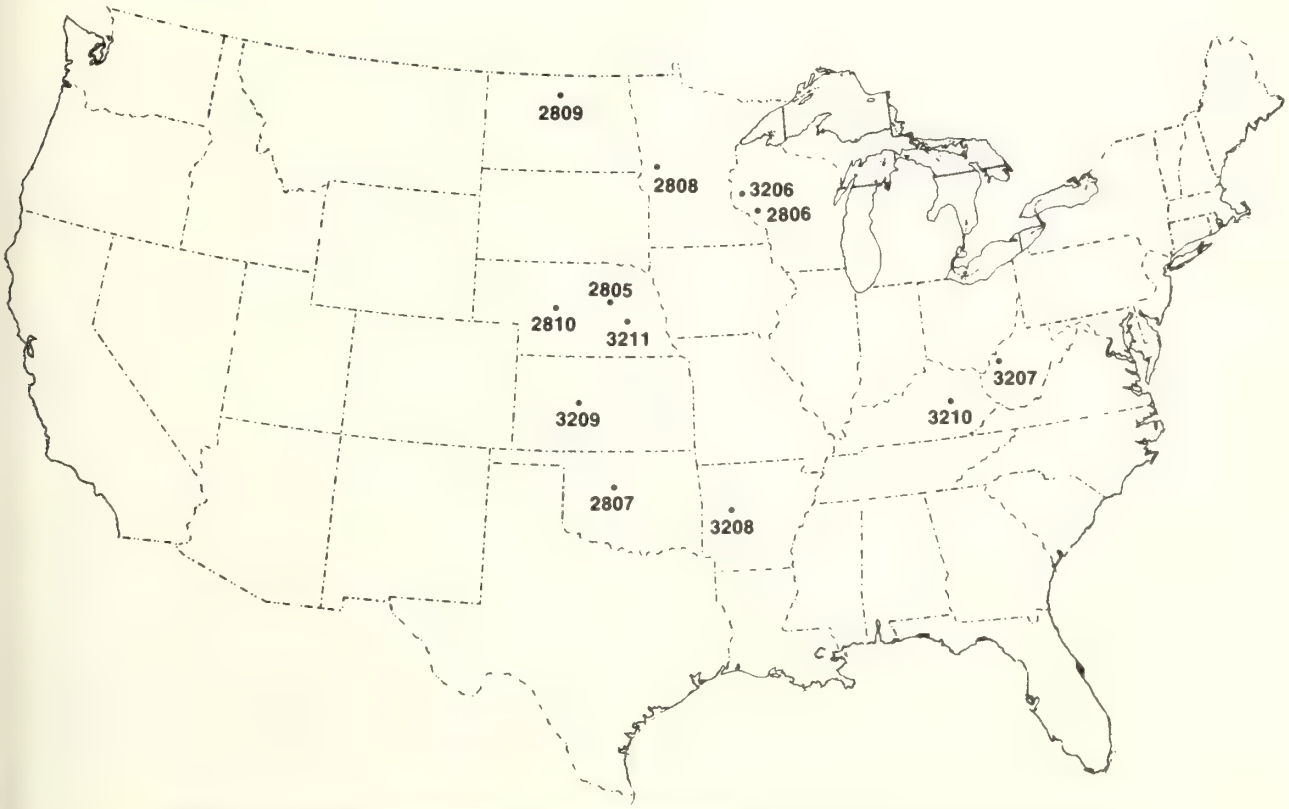


Figure 1.—Geographic distribution of eastern redcedar seed sources being tested on the Denbigh Experimental Forest in north central North Dakota.

Table 1.—Survival and total height of 12 seed sources of eastern redcedar on the Denbigh Experimental Forest in north central North Dakota

Source	1967 (4 yrs.)		1973 (10 yrs.)		1976 (13 yrs.)			Foliage color		
	Survival	Height	Survival	Height	Survival	Height[1]	Percent[2]	Red	Purple	Green
	(%)	(cm)	(%)	(cm)	(%)	(cm)			(%)	
2809 N. Dak. shelterbelt	98	38	98	124	98	179 b	107	41	54	5
2808 Minn.	92	40	92	116	92	179 bc	106	43	38	19
2806 Wis.	78	48	75	138	75	183 b	109	40	23	37
3206 Wis.	75	38	72	113	72	134 de	80	38	59	3
3211 Nebr.	30	24	30	109	28	173 bc	103	17	58	25
2805 Nebr.	28	22	22	106	20	147 cd	87	11	56	33
2810 Nebr. plantation	100	47	100	128	100	205 a	122	32	32	36
3209 Kans.	45	19	45	85	45	109 e	65	44	17	39
3207 W. Va.	20	15	15	66	15	64 f	38	33	0	67
3210 Ky.	0									
2807 Okla.	0									
3208 Ark.	0									
Plantation Mean						168				

[1]*Means followed by the same letter are the same (>0.05).*
[2]*Percent of plantation mean.*

All but one of the six best-growing sources can be considered central and northern Great Plains sources. An exception is western Wisconsin (2806). Even though that source is not from a Great Plains longitude, it originates from a latitude similar to those from the central and northern Plains.

Trees from Nebraska seed sources generally survived and grew well. Plant material can often be moved relatively short distances northward with improved growth. Early indications from provenance tests of ponderosa pine and green ash in North Dakota are that trees from certain Nebraska sources grow better than trees from local North Dakota sources.

Trees from several sources showed some promise, but their combined performance of survival and height growth has made them poor candidates for North Dakota. For example, trees from sources 3206 (Wisconsin) and 3209 (Kansas) survived reasonably well after their initial losses, but their height growth was not good. All trees died from a single seed source each in Kentucky, Oklahoma, and Arkansas. They were evidently unable to withstand the harsh climatic conditions of the test site.

Winter Foliage Color

Winter color is one of the foliage characteristics associated with regional distribution of *Juniperus* (Van Haverbeke and Read 1976). Foliage color was evaluated during winter 1973). Only three colors were tallied: red, purple, and green. Seed sources and corresponding percentage of the trees predominantly displaying one of the colors is shown in table 1.

Trees from northern latitude sources (2809, 2808, 2806, 3206) were about equally divided between red and purple foliage, with relatively few green trees. Trees from Nebraska (3211, 2805, 2810, 3209) were most often purple or green. Minckler and Ryker (1959), however, found no predominantly green winter foliage among trees from Nebraska seed sources.

Trees from the Kansas source were mostly red or green, while the trees from West Virginia were only red or green. Minckler and Ryker (1959) also reported no purple winter foliage color among trees from far-eastern U.S. sources.

Animal Damage

Past experience in the Denbigh Experimental Forest indicates juniper is susceptible to deer browsing. Habitat on the experimental forest is highly suitable for deer. Deer have browsed heavily on nearly all trees in this plantation, without apparent preference for any sources. One of the trees from Nebraska source 2810 that was not heavily browsed has developed well (fig. 2). Adapted trees will eventually grow above deer browse height, but browsing effects will remain (fig. 3). In some cases, multiple stems were probably caused by deer browsing. More deer activity is concentrated in this plantation than would be found in an average farmstead or field windbreak. Browsing could be a problem, however, if juniper windbreaks are located near other areas that provide good deer habitat.

Figure 2.—Tall, moderately dense crown tree from Custer County, Nebraska seed source 2810, free of deer browsing.

Figure 3.—Browsing by deer has reduced wind control effectiveness of this tree, even though the top is now above browse height.

Rabbits and mice sometimes damage junipers. They have caused only minor damage in this plantation. One reason may be because they have many other food sources on the Experimental Forest.

Cedar-apple Rust

Where apple trees grow in the vicinity of junipers, cedar-apple rust infections are common. Very few rust infections were noted, and no pattern of source related infections appeared among the test trees. This is probably because apple trees are not grown in the Experimental Forest vicinity.

Literature Cited

Fowells, H. A. 1965. Silvics of forest trees of the United States. U.S. Dep. Agric., Agric. Handb. 271, 762 p.

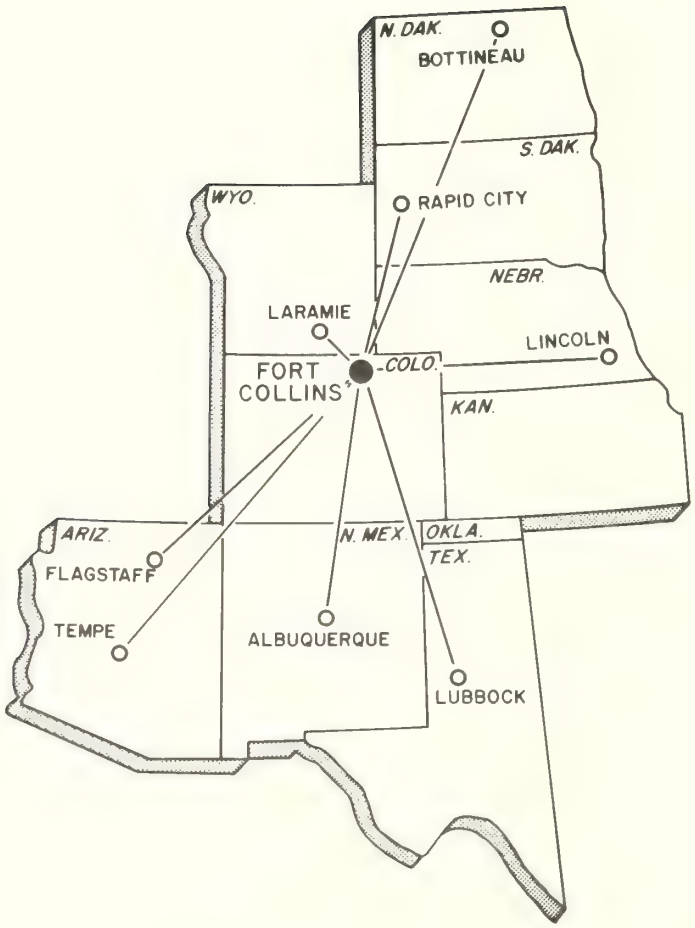
George, Ernest J. 1953. Tree shrub species for the northern Great Plains. U.S. Dep. Agric. Circ. 912, 46 p.

Minckler, Leon S., and Russell A. Ryker. 1959. Color, form, and growth variations in eastern redcedar. J. For. 57(5):347-349.

Read, Ralph A. 1958. The Great Plains shelterbelts 1954. Nebr. Agric. Exp. St. Bull. 441 (Great Plains Agric. Counc. Publ. 16), 125 p.

Van Haverbeke, David F. 1968. A population analysis of *Juniperus* in the Missouri River Basin. Univ. Nebr. Student News Serv. 38, 82 p.

Van Haverbeke, David F., and Ralph A. Read. 1976. Genetics of eastern redcedar. USDA For. Serv. Res. Pap. WO-32, 17 p. U.S. Dep. Agric., For. Serv., Wash., D.C.


N. DAK.
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

st 1979

RESEARCH NOTE RM-372

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

CLEMSON UNIVERSITY LIBRARY
JAN 8 1980
SCI., TECH. & AGR. DIV.

Microbial Populations in Undisturbed Soils and Coal Mine Spoils in Semi-arid Conditions[1]

R. V. Miller, E. E. Staffeldt, and B. C. Williams[2]

Microbial populations in undisturbed soils and in coal mine spoils exposed for 1, 8, and 14 years are listed for semi-arid conditions in New Mexico.

Keywords: Microbial populations, soil flora, mine spoils, reclamation.

Introduction

In the vast coal fields of the Western and Southwestern states, much of the coal is less than 33 m below the surface, making strip mining the most economical and feasible method of extraction. Problems of reclamation and revegetation of strip mine spoils are compounded in these semi-arid states by long periods with a lack of moisture and generally very low moisture. Vegetation and other forms of life return very slowly to spoil sites.

This study provided an opportunity to make a single measurement taken in March of microbial population levels on mine spoils 1, 8, and 14 years old, and on two undisturbed sites. Although statistical comparisons cannot be made in this study, it does provide baseline data for microbial populations found on Southwestern mine spoil material; data that at present is lacking in the literature.

Knowledge of how microbial populations fluctuate may be helpful in estimating how quickly coal mine spoils may be revegetated. Since microbes are the decomposers of biomass, large variations in producer and/or consumer biomass levels, or chemical variations, are reflected in the microbial populations. Microbial populations and numbers may possibly be of use in indicating plant species to choose for revegetating mine spoils since microbial populations and numbers show some association with the types of successional plant species, the rate of succession, and the establishment of a stable surface community.

Methods and Materials

Site Characterization

The study was conducted on McKinley mine property located near Gallup, N. Mex., in a semi-arid grassland-forest ecosystem. The two predominant plant species on nearby unmined areas are one-seed juniper (*Juniperus monosperma*) and blue grama grass (*Bouteloua gracilis*) on slopes, and sagebrush (*Artemisia* spp.) and blue grama in the arroyo or valley areas. Both juniper and sagebrush

[1]*Research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. The authors appreciate the cooperation and assistance of the Pittsburgh and Midway Coal Co. in providing study areas, facilities, and manpower for the field investigations. Supervision for this research, funded by the Rocky Mountain Forest and Range Experiment Station, was provided by Earl F. Aldon, Project Leader for Mine Spoil Reclamation in the Southwest research, at the Station's Research Work Unit in Albuquerque, in cooperation with the University of New Mexico. Station's central headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2]*Miller is Graduate Student, Staffeldt (deceased) was Professor of Biology, and Williams is Professor of Soils, New Mexico State University, Las Cruces.*

sites were studied in the unmined areas. The average rainfall is less than 25 cm per year, with nearly half occurring in July through October.

Mining began at the McKinley site in 1961; spoil areas 1, 8, and 14 years old were available for study. The spoils were the mixed overburdens of the coal seams, and varied greatly in textures due to mixing of various strata. Site variables were kept as constant as physically possible.

Sampling Procedure

Microbial populations were studied from both undisturbed soils and mine spoils. In the undisturbed soils, samples were taken from depths of 0 to 20 cm, 20 to 35 cm, and 35 to 50 cm in both the juniper and sagebrush areas. A composite sample from a depth of 0 to 35 cm was taken in the three age classes of spoil material.

Chemical properties were determined by standard laboratory procedures of the New Mexico State University Soil and Water Testing Laboratory.

Media and Cultivation

Serial dilutions of each soil were made in water and plated on enrichment media (Waksman and Fred 1922). The enrichment media (table 1) were prepared for the isolation of aerobes, anaerobes, microaerophils, yeasts, fungi, actinomycetes, nitrate reducers, nitrogen fixers, and sulfate reducers. Three replicates of each serial dilution were made and colony numbers averaged.

In addition, fungal populations were isolated and characterized by an organic trap technique.[3] Fungi were then counted and characterized as to genus.

Results

In the unmined juniper and sagebrush areas, bacterial populations decreased as depth below the surface increased. Bacterial populations were higher under sagebrush than under juniper. The populations in both soils were usually around 10^5 organisms per gram of soil in the upper soil horizons, decreasing to 10^4 organisms in the deeper horizons. A typical diagram for nitrogen fixing bacteria is shown in figure 1.

A listing of microbial populations in mine spoils exposed 1, 8, and 14 years is shown in table 2. Chemical characteristics of the spoils are shown in table 3.

A few genera of fungi became established after 1 year (table 4). After 8 years, there was a greater diversity and number of individuals in the population, and two antibiotic fungal species emerged after 14 years.

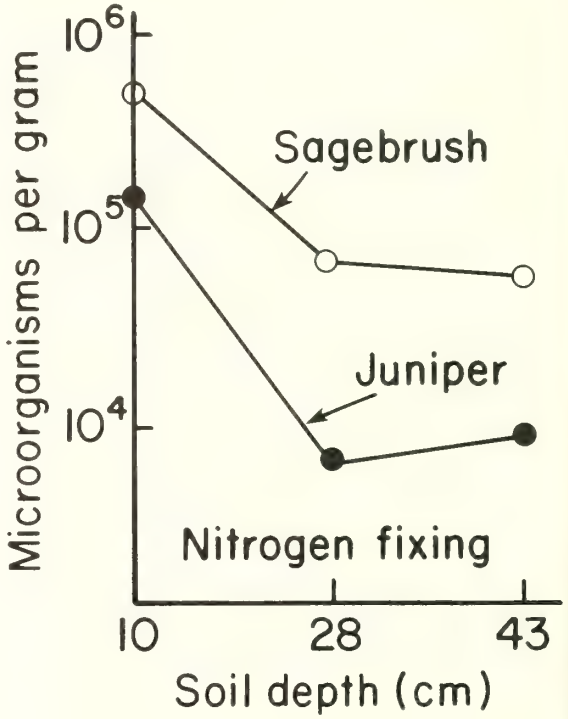


Figure 1.—An example of vertical distribution of bacteria populations in undisturbed soils.

[3]*For details, contact Rocky Mountain Forest and Range Experiment Station, 5423 Federal Building, 517 Gold Ave., S.W., Albuquerque, N. Mex. 87101.*

Table 1.—Media used for isolating microorganisms

Medium	Organisms selected for	Reference
Trypticase soy	Aerobic microorganisms	Rhode (1973)
Czapek dox	Fungi	Czapek (1902), Dox (1910), Thom and Church (192
Nitrate reduction agar	Nitrate-reducing organisms	Difco Laboratories, Inc. (1953)
Sulfate reduction	Sulfate-reducing organisms	Adams and Postgate (1961), Butlin et al. (1949)
Yeast isolation medium	Yeasts and aerobic bacteria	
Actinomycete isolation media	Streptomycetes and aerobic bacteria	Difco Laboratories, Inc. (1953)
Nitrogen fixing	Free living N^2-fixing organisms	Parkinson et al. (1971)
Fluid thioglycollate	Microaerophils	Brewer (1940)
Brewers anaerobic	Anaerobic organisms	Brewer (1942)

Table 2.—Average microbial populations from 0-35 cm deep in undisturbed soils and in mine spoil materials exposed 1, 8, and 14 years to semi-arid conditions.

Medium	Mine spoil materials exposed for:			Undisturbed soils	
	1 yr	8 yr	14 yr	Sagebrush	Juniper
Trypticase soy	$1.2X10^5$	$1.3X10^6$	$1.3X10^5$	$7.9X10^5$	$6.1X10^5$
Czapek dox	$1.2X10^5$	$5.7X10^5$	$1.4X10^5$	$8.4X10^5$	$1.6X10^5$
Nitrate reducer agar	$2.2X10^5$	$4.0X10^5$	$1.7X10^5$	$7.7X10^5$	$2.5X10^5$
Sulfate reduction	$1.3X10^2$	$1.2X10^3$	$8.2X10^3$	$1.3X10^4$	$7.0X10^2$
Yeast isolation medium	$1.2X10^4$	$1.4X10^5$	$4.6X10^4$	$2.3X10^5$	$2.2X10^4$
Actinomycete isolation media	$2.5X10^4$	$3.2X10^5$	$8.4X10^4$	$3.2X10^5$	$1.2X10^5$
Nitrogen fixing	$1.0X10^5$	$5.1X10^5$	$8.3X10^4$	$3.6X10^5$	$8.5X10^4$
Fluid thioglycollate	$4.6X10^3$	$1.3X10^5$	$4.0X10^4$	$7.2X10^5$	$1.1X10^4$
Brewers anaerobic	$9.8X10^4$	$7.0X10^4$	$4.1X10^3$	$3.5X10^4$	$2.7X10^3$

Table 3.—Chemical characteristics of undisturbed soils and of mine spoil materials exposed 1, 8, and 14 years to semi-arid conditions

Chemical characteristics	Mine spoil materials exposed for:			Undisturbed soils	
	1 yr	8 yr	14 yr	Sagebrush	Juniper
pH	6.90	6.70	6.95	7.57	7.75
$ECX10^3$	4.21	2.34	2.75	0.81	0.47
Inorganic C (%)	0.00	0.74	2.07	0.79	0.25
Organic C (%)	4.40	15.52	2.04	0.00	0.02
Total C (%)	4.35	16.26	4.11	0.79	0.28
NO_3- (ppm)	240.00	3.05	29.20	0.16	0.15
Ca++ (me/1)	30.25	1.86	21.09	7.65	3.30
Mg++ (me/1)	17.12	1.02	6.45	0.97	0.87
Na+ (me/1)	15.57	21.42	9.59	0.40	0.73
K+	0.79	0.50	0.18	0.25	0.15
SO_4- (me/1)	41.86	15.73	21.87	0.36	0.54
Cl- (me/1)	2.12	1.10	3.01	0.18	0.12
HCO_3- (me/1)	4.40	5.19	6.85	8.40	4.35
SAR	3.20	23.66	2.50	0.55	0.24

Table 4.—Genera and numbers of microorganisms in mine spoil and juniper soils obtained by the organic trap method.

Genus	Mine spoil age			Juniper soil
	1 year	8 years	14 years	
Alternaria		3		
Basidiomycetes			9	1
Chaetomium		1	3	1
Fusarium		9		9
Myrothecium		1		5
Penicillium		3		
Phoma		1		
Pythium		2		3
Rhizopus		2		
Stachybotrys	9	1		
Tetracocco		2		
Verticillium		2		
Nematodes		2		6
Bacteria	6	7		6
Total Numbers of:				
Genera	2	13	2	7
Individuals	15	36	12	30

Literature Cited

Adams, M. E., and J. R. Postgate. 1961. On sporulation in sulphate-reducing bacteria. J. Gen. Microbiol. 24(2): 291-294.

Brewer, J. H. 1940. Clear liquid mediums for the "aerobic" cultivation of anaerobes. J. Am. Med. Assoc. 24(8):598-600.

Brewer, J. H. 1942. A new petri dish cover and technique for use in the cultivation of anaerobes and microaerophils. Science 5(2475):587.

Butlin, K. R., M. E. Adams, and M. Thomas. 1949. The isolation and cultivation of sulphate-reducing bacteria. J. Gen. Microbiol. 3(1):46-59.

Czapek, F. 1902. Beitrage zur Chemischen Physiologic und Pathologic. Band 1. Heft 10-12. p. 540.

Difco Laboratories, Inc. 1953. Difco manual of dehydrated culture media and reagents for microbiological and clinical laboratory procedures. 9th ed. p. 184-185. Detroit, Michigan.

Dox, A. W. 1910. The intracellular enzyms of penicillum and aspergillus, with special reference to those of *Penicillium camemberti*. U.S. Dep. Agric., Bur. Animal Ind. Bull. 120, 70 p.

Parkinson, D., T.R.G. Gray, and S. T. Williams (eds.). 1971. Methods for studying the ecology of soil microorganisms. International Biological Programme Handbook 19. Blackwell Scientific Publications, Oxford, England. p. 105-109.

Rhode, P. A. (ed.). 1973. BBL Manual of Products and Laboratory Procedures, Fifth Edition. Becton, Dickinson and Co., Cockeysville, Maryland. p. 78-81.

Thom, C., and M. B. Church. 1926. The Aspergilli. Williams and Wilkins Co., Baltimore, Maryland. p. 39.

Waksman, S. A., and E. B. Fred. 1922. A tentative outline of the plate method for determining the number of microorganisms in the soil. Soil Sci. 14:27-28.

tember 1979

RESEARCH NOTE RM. 373

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND

Aerial Stand Volume Table for Plains Cottonwood in Eastern Colorado

Carleton B. Edminster[1] and James R. Getter[2]

An aerial stand volume table is developed for plains cottonwood (*Populus deltoides* var. *occidentalis* Rydb.) in eastern Colorado. Gross volume in cubic feet per acre is related to average stand height and crown closure percent.

Keywords: Forest measurement, aerial volume table, stand volume estimates, *Populus deltoides* var. *occidentalis*.

The need for efficient inventories of forest resources in eastern Colorado has led to development of the aerial volume table presented in this note. This table is an extension of previously developed relationships for tree volumes and point-sampling factors applicable to plains cottonwood (*Populus deltoides* var. *occidentalis* Rydb.) (Edminster et al. 1977).

The cottonwood forest along the South Platte River bottom in Morgan County was selected as the primary area for this study. This relatively pure forest covers an area approximately 0.75 mile (1.2 km) wide by 45.6 miles (73.4 km) long. Orchards, shelterbelts, and ornamental plantings were excluded from the study.

Personnel of the Colorado State Forest Service measured trees on sample plots and interpreted aerial photographs.

[1]*Mensurationist, Rocky Mountain Forest and Range Experiment Station. Central headquarters maintained in Fort Collins, in cooperation with Colorado State University.*

[2]*Senior Environmental Analyst, H.R.B.-Singer, Inc.; formerly Resource Inventory Forester, Colorado State Forest Service.*

Development of Aerial Stand Volume Table

Sample plots were selected using black and white panchromatic vertical aerial photographs of the forest. A grid scaled to 1-acre (0.405-ha) plots was superimposed on the 1:20,000 nominal scale photographs. Using this grid, 29 plots were selected at random for photographic and ground measurement.

The proportion of forest canopy occupied by trees, crown closure percent, and average total height of trees in the plot were determined on the photographs. Crown closure was used in the volume relationship to replace basal area or number of trees per acre because these variables cannot be determined from available photography (Avery 1977). Crown closure percent was determined from ocular estimate by experienced photographic interpreters. Total height of trees or clumps of trees was measured using a parallax bar with stereoscopic photo pairs. Average height for the plot was computed from the heights of individual trees and clumps of trees weighted by their respective contribution to crown closure percent.

Ground measurements included checks of both pilot crown closure percent and average height. The

diameter at breast height measured outside the bark and total height of individual trees or stems within clumps was recorded. Total volume inside the bark in cubic feet for the plot was then determined using the available tree volume equation for the merchantable stem, excluding a 0.5-foot (0.15-m) stump, and major branches to a 2-inch (5.1-cm) diameter (Edminster et al. 1977).

Values presented in table 1 were computed from the regression equation:

$$V = -175.671 + 9.817H + 0.401HC$$
$$R^2 = 0.72 \qquad Sy.x = 196.3$$

where

V = gross stand volume in cubic feet per acre,
H = average total height of the stand in feet,
C = crown closure percent.

The equivalent volume equation in System International metric units is:

$$V_m = -12.292 + 2.254H_m = 0.092H_mC$$

where

V_m = gross stand volume in cubic meters per hectare,
H_m = average total height to the stand in meters.

Field Checks to Adjust Photo Volumes

Volumes for pure stands given in table 1 do not include allowance for defective trees or unusable portions of trees. Therefore, a portion of interpreted photo plots from an aerial cruise should be sampled in the field to determine what adjustment factors are needed to convert gross volume estimated from aerial photos to net ground volumes. A double sampling procedure would provide a mechanism for estimating these adjustment factors (Cochran 1963).

Literature Cited

Avery, T. Eugene. 1977. Interpretation of aerial photographs. 3rd ed. 392 p. Burgess Publishing Co., Minneapolis, Minn.

Cochran, William G. 1963. Sampling techniques, 2nd ed. 413 p. John Wiley and Sons, Inc., New York.

Edminister, Carleton B., James R. Getter, and Donny R. Story. 1977. Past diameters and gross volumes of plains cottonwood in eastern Colorado. USDA For. Serv. Res. Note RM-351, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Table 1. Gross stand volumes inside bark (in cubic feet per acre) for plains cottonwood in eastern Colorado

Average total height (feet)	% crown closure											
	5	10	15	20	25	30	35	40	45	50	55	60
20	61	101	141	181	221	261	301	341	382	422	462	502
25	120	170	220	270	320	371	421	471	521	571	621	671
30	179	239	299	359	420	480	540	600	660	720	780	841
35	238	308	378	449	519	589	659	729	799	870	940	1,010
40	297	377	458	538	618	698	778	859	939	1,019	1,099	1,179
45	356	447	537	627	717	807	898	988	1,078	1,168	1,259	1,349
50	415	516	616	716	816	917	1,017	1,117	1,217	1,318	1,418	1,518
55	475	585	695	805	916	1,026	1,136	1,246	1,357	1,467	1,577	1,688
60	534	654	774	895	1,015	1,135	1,255	1,376	1,496	1,616	1,737	1,857
65	593	723	853	984	1,114	1,244	1,375	1,505	1,635	1,766	1,896	2,026

Computed from: V = -175.671 + 9.817 H + 0.401 HC
Heights listed are midpoints of 5-feet classes.
Crown closures listed are midpoints of 5% classes.
Blocks indicate extent of basic data.

RM-374

tember 1979

RESEARCH NOTE RM-374

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

CLEMSON UNIVERSITY LIBRARY
JAN 8 1980
SCI., TECH. & AGR. DIV.

A Portable Irrigation System for Remote Sites[1]

George Garcia[2]

A simple but highly reliable truck-mounted system delivers 500 gallons of water through 500 emitters on 10 drip lines in about 50 minutes. It can be used for seedling establishment, or to maintain transplants. It should prove useful in remote locations with critical plant establishment needs.

Keywords: Irrigation systems, revegetation

Revegetating steep slopes after mechanical disturbances such as mining or dam construction is often difficult, especially where natural precipitation is low. Pressurized water systems are seldom available at these remote sites. To assist in revegetating slopes in remote areas, we developed a portable irrigation system consisting of a 500-gallon tank and two centrifugal gasoline engine pumps mounted on a 1-1/2 ton truck (fig. 1).

Description of the System

The pump for filling the tank is a 3-1/2-h.p. gasoline engine centrifugal with a high rated delivery. This was used to lift water into the tank from a reservoir. The irrigation delivery pump is a 3-h.p. gasoline engine centrifugal with a low delivery rating for low pressures. Suction hose is connected from the delivery pump with a hand-tightened plastic union onto a pressure regulator valve. Pressure is maintained at 15 psi to deliver the desired flow. A plastic filter with a 200-mesh synthetic screen, and an externally attached faucet, are installed behind the pressure regulator on the main supply line. The faucet provides water for washing the screen after each use.

The supply line is assembled with 2-inch PVC (polyvinyl chloride) pipe, although steel or plastic lines may be used. Drip irrigation lines with attached compression fittings are connected to flow controls rated at 1 gallon per minute, and to the supply line tees (fig. 2). Poly emitter hose with emitters spaced 1 ft apart is used for the drip irrigation line. The length of the poly hose can vary to accomodate individual needs. Emitters may be installed individually at any desired spacing. Compression end plugs seal the ends of the irrigation lines.

A Field Test

The system was tested on fairly steep east- and west-facing slopes. The east-facing irrigation plot was 75 ieet long upslope, 50 feet long on the contour, on a 30% slope. The west-facing plot was 50 feet long upslope, 50 feet long on the contour, and a 38% slope.

[1]The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.

[2]Forestry Technician, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.

Grasses and shrubs were drilled on the two slopes prior to installation of water lines. Plots were straw mulched and mechanically crimped.

Irrigation was begun on May 9, 1977. Approximately 50 minutes were required to deliver 500 gallons of water through the 500 emitters on the 10 drip lines. The screen was washed routinely after every watering. Plots were irrigated three times weekly for the first 3 weeks during germination of the seeded species, then twice a week for 5 more weeks. Natural precipitation then maintained the seedlings through the growing season. After the first growing season, plant densities averaged two plants per square foot on irrigated plots which was twice as much as the density on non-irrigated similar areas.

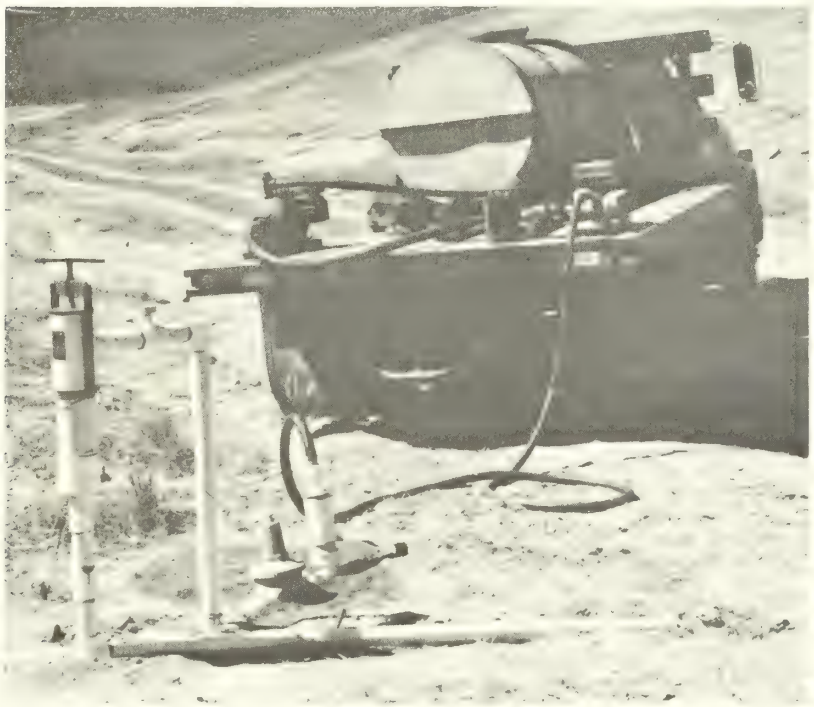


Figure 1.—A portable irrigation system.

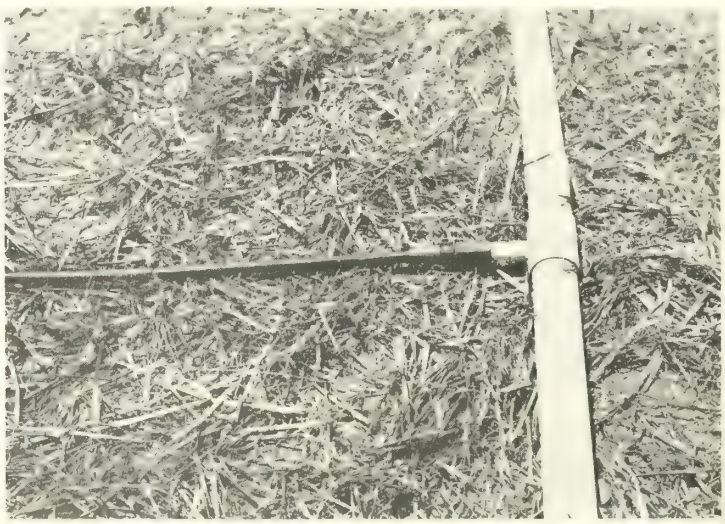


Figure 2.—Drip lines with attached compression fittings are connected to flow controls, and to the supply line tees.

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SCI., TECH. & AGR. DIV.

Effects of Tree Distribution and Canopy Cover on Classification of Ponderosa Pine Forest from LANDSAT-1 Data[1]

Roy A. Mead, Richard S. Driscoll, and James A. Smith[2]

Many factors confound computer-assisted classification of forest types from LANDSAT-1 digital data in a mountainous area of central Colorado. Tree distribution and variable forest canopy cover were considered in this study to determine if classification could be improved by accounting for these factors.

Keywords: Forest classification, computer mapping, remote sensing

Introduction

Several studies have been made on computer-assisted mapping of forest cover types from LANDSAT-1 data. Krumpe et al. (1973) found LANDSAT-1 data could be used in the classification of vegetation types for a forest test site in California. However, not all attempts to map vegetation from satellite data have been as successful. Hoffer and LARS Staff (1973) identified several sources of error contributing to wide variations in spectral signatures, possibly because of slope, aspect, and plant canopy cover. Driscoll et al. (1974) found that adjusting the spectral signature of a ponderosa pine (*Pinus ponderosa* (Laws Dougl.) forest for slope improved classification accuracy. All of these investigators concluded that much research is needed to investigate the many ground-associated factors influencing computer-assisted analysis of remote sensing data.

In addition, these early studies showed that variations in sun altitude and azimuth can affect the spectral reflectance from forest canopies and confound classification accuracies (LeSchack 1971). Hoffer and LARS Staff (1973) found aspect, slope, and crown cover could be correlated with the reflectance of light from a forest canopy, thereby affecting classification accuracy. Since forests are comprised of continua for all of these factors, an understanding of the effect of each on spectral signature is necessary to improve classification accuracies.

Preliminary data on the effect of different combinations of slope, aspect, and cover of a ponderosa pine forest on the apparent reflectance of the LANDSAT-1 scanner produced significantly different response values. From these observations, we hypothesized that, by correcting for some of these factors, classification of that forest type could be improved.

There were two main purposes for conducting this study. The first was to investigate the effect of forest canopy cover and tree distribution on the apparent spectral signature from a single forest type, ponderosa pine. The second was to determine whether such factors could be corrected for to improve the accuracy of computer-assisted classification of forest types.

[1]*Work reported here was done in cooperation between the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, and the Earth Resources Department, Colorado State University.*

[2]*Authors are, respectively, Assistant Professor of Forestry, Virginia Polytechnic Institute and State University, Blacksburg; Program Manager, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.; and Associate Professor, Department Forestry and Wood Sciences, Colorado State University, Fort Collins.*

Methods and Materials

The study area was in and around the Manitou Experimental Forest in central Colorado, a typical area of the east slope of the Rocky Mountains with a variety of aspects and slope steepnesses.

A scene recorded on August 15, 1973, by the LANDSAT-1 multi-spectral scanner was analyzed in the form of digital values, each representing the instantaneous field of view of the scanner, approximately 79 m^2. The spectral response was measured by the scanner in four spectral bands: band 4 (0.5-0.6 μ), band 5 (0.6-0.7 μ), band 6 (0.7-0.8 μ), and band 7 (0.8-1.1 μ). These data are in the form of four arrays (one for each band) recorded on magnetic tape in a format compatible with computer processing systems.

A set of 24 sample plots of ponderosa pine forest on east-facing moderately steep (less than 8%) slopes was selected. The size of these plots corresponded to a 4 by 5 array of resolution elements in the digital satellite data representing a rectangular area approximately 315 by 395 m or 12.5 ha on the ground.

Two types of measurements were made on each plot. First, a computer processing system RECOG[3] by Smith et al. was used to determine the average spectral response in each of the 4 bands from the 20 resolution elements making up each plot. Second, the tree canopy cover for each plot was estimated by interpretation of 1:50,000 color infrared photos, flown at approximately the same time that the imagery was recorded.

[3]*Smith, J. A., G. Hartinger, and R. A. Mead. 1974. Computer applications support for ERTS investigation. Final Rep. Coop. Agreement 16-338-CA. Rocky Mt. For. and Range Exp. Stn., USDA For. Serv., Fort Collins, Colo. 28 p. (unpubl.)*

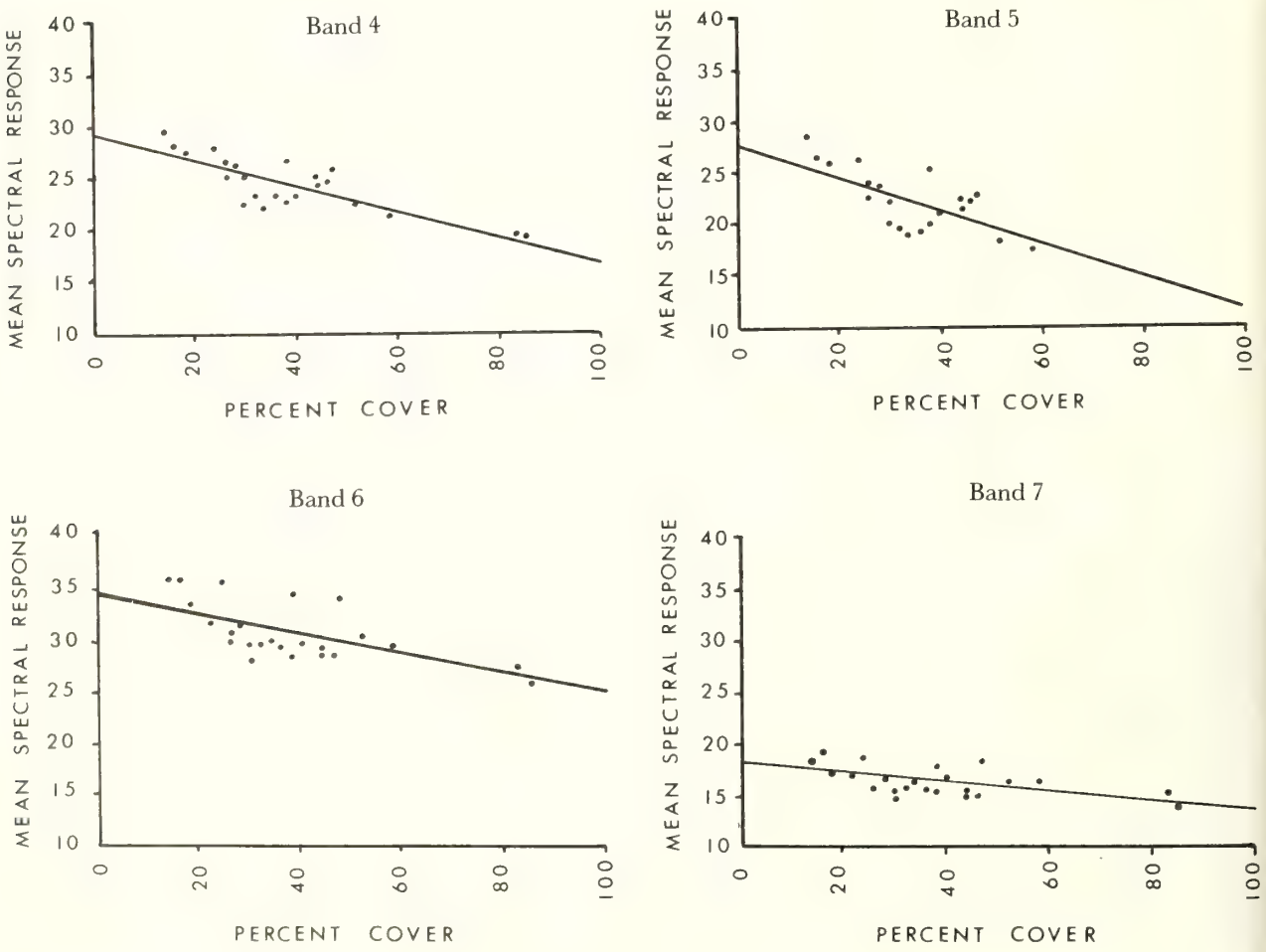


Figure 1. The mean spectral response of ponderosa pine forest on gradual (less than 8%) east-facing slopes as a function of percent tree canopy cover.

Results and Discussion

Tree canopy cover for the 24 plots of ponderosa pine forest varied between 14% and 84%, and the mean spectral response also varied considerably. Figure 1 displays the apparent relationship between the mean spectral response of the ponderosa pine forest plots in each band and percent tree canopy cover.

The following regression models were determined to describe the possible relationships between the mean spectral response, Y, and the tree canopy cover, X, in the four spectral bands:

$Y = 29.11 - 0.12x : r^2 = 0.68$; C.I. = 0.41 – 0.85 (band 4)
$Y = 27.86 - 0.16x : r^2 = 0.70$; C.I. = 0.43 – 0.86 (band 5)
$Y = 34.49 - 0.10x : r^2 = 0.42$; C.I. = 0.12 – 0.69 (band 6)
$Y = 17.93 - 0.04x : r^2 = 0.31$; C.I. = 0.42 – 0.61 (band 7)

The mean spectral response varied considerably because of changes in tree canopy cover, at least in bands 4 and 5. In general, the plots sparsely covered with trees had higher spectral responses than heavily forested plots. Gates et al. (1965) also found that coniferous plants have lower reflectances in both the visible and near-infrared than any of the other types of plants he measured.

The standard deviations of the signatures of each forest plot provided an interpretable relationship between the distribution of the trees within the plots and both the mean signature and the standard deviation of the mean signature. Plots with uniformly distributed trees had lower standard deviations than those in which the trees were grouped. For example, two plots of ponderosa pine forest (fig. 2) had similar tree canopy cover (26% and 28%) but tree distribution was very different. The standard deviations of the average spectral signatures for plot (a) in the four spectral bands were 2.41, 3.02, 3.19, and 1.34, while for plot (b), with more uniformly distributed trees, they were 0.86, 1.28, 1.23, and 0.74. In plot (a) some resolution elements represent the reflectance of predominantly non-forest vegetation, while others represent the reflectance from a dense forest canopy. Therefore, the digital values for individual forested and non-forested areas within plot (a) varied considerably from the overall mean for the plot. In plot (b), however, the area represented by each resolution element included a mixture of both forest and non-forest vegetation, and resulting intermediate values did not vary greatly from the mean.

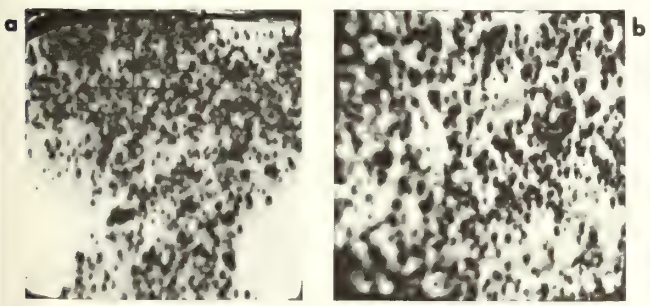


Figure 2. Although these two ponderosa pine forest plots have similar tree canopy cover, the trees in plot (a) are more clumped with open grassland between, resulting in higher standard deviations of the MSR, than in plot (b) in which the trees are more evenly distributed.

Comparing plots of ponderosa pine forest having similar total crown closure but varying tree distribution showed that the mean signatures could also vary significantly. Thus the distribution of vegetation within a sampling unit may affect the average signature as well as the standard deviation.

Conclusion

Many factors may account for the errors in classification of forest types from LANDSAT data. In this study we examined two of these factors: crown closure and tree distribution. It was found that plots of ponderosa pine with high crown closures generally had lower signatures than plots with low crown closure. Regression models were developed that adequately described this relationship for the two infrared bands of the LANDSAT data. Also, variations in tree distribution within plots can change the mean spectral response of ponderosa pine forest and thus classification accuracy.

Literature Cited

Driscoll, Richard S., Richard E. Francis, James A. Smith, and Roy A. Mead. 1974. ERTS data for classifying native plant communities — central Colorado. p. 1195-1211. *In* Proc. 9th internatl. symp. on remote sensing of environ., Univ. Mich., Ann Arbor.

Gates, D. M., H. J. Keegan, J. C. Schleter, and V. R. Weidner. 1965. Spectral properties of plants. Appl. Opt. 4:11-20.

Hoffer, R. M., and LARS Staff. 1973. Techniques for computer-aided analysis of ERTS-1 data, useful in geologic, forest and water resource surveys. LARS Inf. Note 121073. The Lab. for Appl. Remote Sensing, Purdue Univ., W. Lafayette, Ind. 22 p.

Krumpe, Paul, James D. Nichols, and Donald T. Lauer. 1973. ERTS-1 analysis of wildland resources using manual and automatic techniques. p. 50-66. *In* Manage. and util. remote sensing data symp. proc. Sioux Falls, S. Dak.

LeSchack, Leonard A. 1971. Automatic data processing of forest imagery. Photogramm. Eng. 37:885-896.

ber 1979

RESEARCH NOTE RM- 376

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SCI., TECH. & AGR. DIV.

Phenology and Rate of Height Growth of Some Forbs in the Southwestern Ponderosa Pine Type

Warren P. Clary and William H. Kruse[1]

In a 3-year study, two of six primary forb species had possible value as range readiness indicators. Species varied between seasons and sites as available sources of deer forage. Twenty-four secondary forb species showed a diversity of palatable green forage becoming available throughout the growing season.

Keywords: Phenology, plant development, deer forbs, southwestern ponderosa pine type.

Management Implications

Results suggest that the common dandelion may have indicator value for spring "range readiness" of native herbaceous forage. A diversity of green forage is available to deer from mid-spring to early fall in the ponderosa pine vegetation type. The diets of deer reflect this availability: two-thirds of the diet is herbaceous plants (Neff 1974).

Plant development at the Wild Bill Range is 2 weeks later than at the Beaver Creek Watershed. Since the elevation and latitude effects only account for about one-half of this difference, the juxtaposition of a site in relation to major topographic features may be important in predicting phenological development.

Introduction

Knowledge of herbaceous plant phenology may add to understanding of ecosystem functioning and often has practical applicability. Such knowledge can be used as a guide to time of "range readiness," predicting forage quantity and quality, and as an aid in designing grazing systems (Blaisdell 1958, Costello and Price 1939, Jameson 1965). Knowledge of plant phenology is also necessary to effectively time possible herbicide applications.

Forbs often equal or exceed browse in the spring-summer diet of mule deer in north-central Arizona, particularly on treated watersheds (Neff 1974). Since timing, rate, an duration of growth vary greatly among species (Ellison 1954), phenological knowledge of preferred species will provide an additional basis for evaluation of wildlife habitat.

The objective of this study was to provide information on phenology and rate of height growth for a number of forbs in the ponderosa pine type.

Study Areas

Two study areas, located in north-central Arizona near Flagstaff were used: 5 acres of range unit 2 of the Wild Bill Range (Pearson and Jameson 1967); and 5 acres of watershed 12 on the Beaver Creek Watershed (Brown et al. 1974). These locations were selected primarily because earlier tree removal had allowed numerous herbaceous species to flourish. Timber dominated sites have relatively few herbaceous species at a given location, making a study of this type impractical.

[1]*Clary is Principal Range Scientist, Intermountain Forest and Range Experiment Station, Provo, Utah. Kruse is Range Technician, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's headquarters is in Fort Collins in cooperation with Colorado State University.*

Both locations are in the ponderosa pine vegetation type, both cleared of timber, and both have volcanic soils. The aspect of both sites is generally southwest, however the slope is nearly level. The Wild Bill Range location (at the western base of the San Francisco Peaks) is 600 feet higher than the Beaver Creek Watershed location, is on the average 3° to 4° F cooler, and receives about 1-1/2 inches less annual precipitation (table 1).

The Wild Bill Range is a pure stand of ponderosa pine (*Pinus ponderosa* Laws.) (nomenclature follows McDougall 1973) with a herbaceous understory dominated by Arizona fescue (*Festuca arizonica* Vasey) and mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.). The forest stand at Beaver Creek is approximately 85% ponderosa pine and 15% Gambel oak (*Quercus gambelii* Nutt.) and alligator juniper (*Juniperus deppeana* Steud.). The understory is dominated by mutton grass (*Poa fendleriana* (Steud.) Vasey), bottlebrush squirreltail (*Sitanion longifolium* J.G. Smith), and blue grama (*Bouteloua gracilis* (H.B.K.) Lag.).

Methods

Five species were selected at each location for intensive height measurements. These species represented a variety of growth habits and were the primary species studied. Four species, houstonia (*Houstonia wrightii* Gray), dandelion (*Taraxacum officinale* Weber), fleabane (*Erigeron divergens* Torr. and Gray), and wormwood (*Artemisia carruthii* Wood) were studied on both areas. Showy aster (*Aster commutatus* Torr. and Gray) was the fifth species studied at the Beaver Creek Watershed, while conyza (*Conyza schiedeana* (Less.) Cronquist) was the fifth species at the Wild Bill Range. Fifteen individual plants of each species were randomly staked and tagged. This number was sufficient to sample a species height on a given date within a standard error of approximately 12% of the sample mean. Height to the nearest 1/2 inch and phenologic stage were recorded at 2-week intervals throughout three growing seasons. On each 2-week measurement date, the typical phenologic stage was recorded on 24 other forb species and two grass species.

A multivariate profile analysis for differences in average height growth among primary species and dates and their interaction was made using a computer program titled, "Analysis of growth data with repeated measurements."

Results and Discussion

Primary Species

The statistical tests of height growth among species, dates, and species x dates were all highly significant for each of the 3 years of measurement. Heights also varied between the two study areas (figs. 2 through 6). In general, the taller species showed the most variation, while the prostrate species showed the least. Figure 1 illustrates the height and form of the primary species.

Measurements and observations in this study suggest different values and uses for different species. Prostrate plants, such as houstonia (which is inconspicuous and relatively uniform in height), have little value as phenological indicators; however, they may serve as a reliable source of deer forage (Neff 1974), particularly in dry years, because of their consistent year-to-year response (fig. 2). Another prostrate species, dandelion, may have indicator value. The showy yellow blossoms of this

Table 1.—Long term and monthly precipitation and temperature averages for each study location

Precipitation *(inches)*

	Wild Bill Range			Beaver Creek Watershed		
	Winter[1]	Summer	Total	Winter	Summer	Total
Long Term	11.24	10.10	21.34	13.01	9.79	22.80
1970-71	5.02	11.05	16.07	6.21	12.59	18.80
1971-72	6.98	10.10	17.08	8.67	9.61	18.28
1972-73	26.14	7.61	33.75	29.71	5.09	34.80

Temperature *(°F)*

	Wild Bill Range			Beaver Creek Watershed		
	Winter	Summer	Avg.	Winter	Summer	Avg.
Long Term	31.0	52.3	41.7	34.3	56.2	45.2
1970-71	30.3	51.0	40.6	33.0	53.5	43.2
1971-72	31.0	51.2	41.1	33.5	54.7	44.1
1972-73	25.5	50.2	37.8	30.0	54.0	42.0

[1]*Winter = October through March; Summer = April through September*

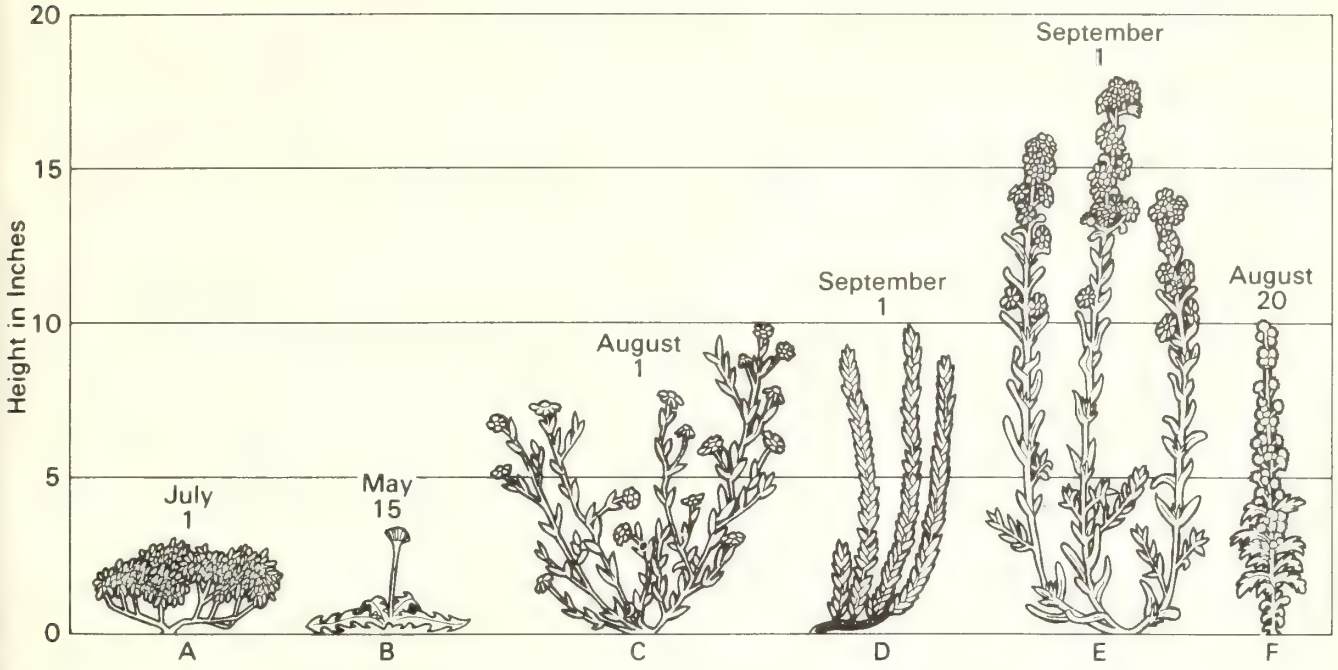


Figure 1.—Illustration of the six primary species showing their height at full bloom (average 3 years): (A) houstonia; (B) common dandelion; (C) fleabane; (D) wormwood; (E) showy aster, and (F) conyza.

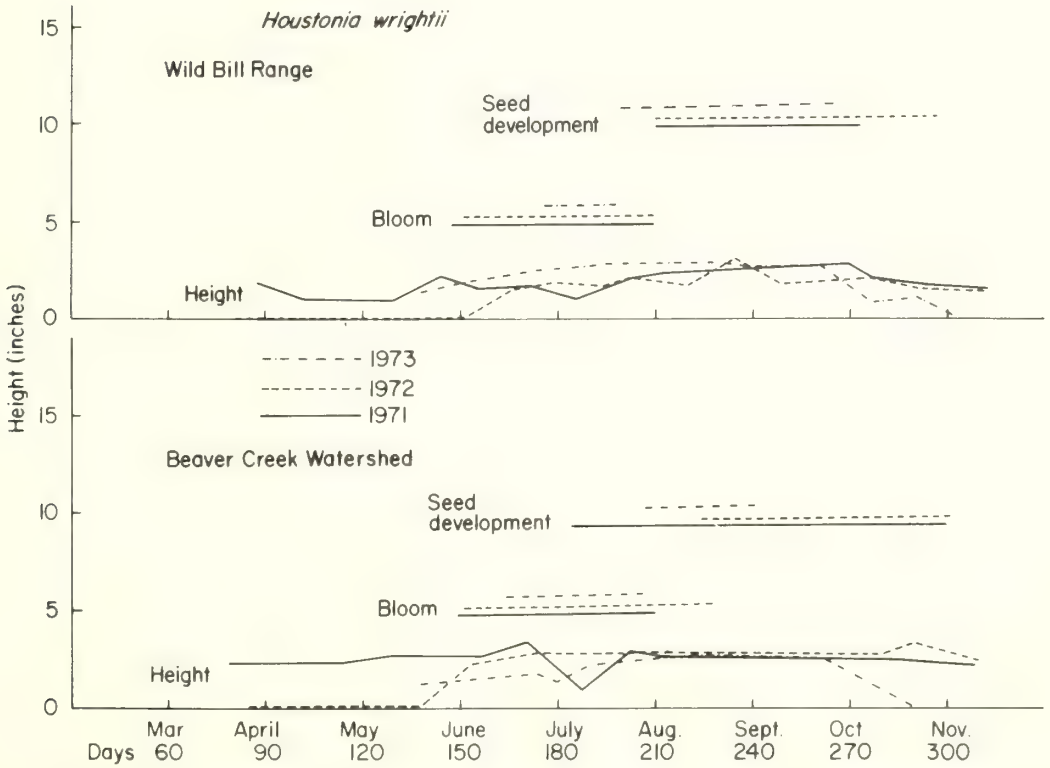


Figure 2.—Height and stage of development for *Houstonia wrightii* at the Wild Bill Range and at the Beaver Creek Watershed.

plant are well known, and their presence may be a signal of "range readiness." For instance, the absence of flowers on May 1 may suggest a late spring and therefore beginning dates for grazing should possibly be set back. The indicator value of dandelion is restricted to early and mid-spring use because this plant is strongly limited by long photoperiods (Solbrig 1971), causing flowering to terminate abruptly in late spring (fig. 3). Further studies of the use of dandelion as an indicator should be conducted under a variety of conditions.

The vegetative growth of spreading fleabane is one of the most responsive to differences in years of any of the plants studied (fig. 4). This abundant plant is an important wildlife food, readily eaten by deer (Neff 1974). However, its availability may be late in some years, as in 1971 when it did not appear until after August 1 at the Wild Bill Range.

Two species which develop late in the growing season, wormwood (measured at both sites) and showy aster (measured at Beaver Creek Watershed only), appear to be little affected by spring weather conditions (figs. 5 and 6). The main year-to-year differences are responses in vegetative growth to summer precipitation. The aster is quite showy when in bloom and palatable to both livestock and wildlife. It often makes up more than 50% of the production of preferred deer forage in dry summers when many summer annuals fail to appear.[2]

The last species for which growth measurements were taken, conyza (at the Wild Bill Range only), failed to appear in 1973 under conditions of a cool wet spring and a dry summer (fig. 6). This plant appeared to be grazed by both cattle and deer or elk, but it is probably of limited value as a phenologic indicator unless perhaps considered on a presence or absence basis.

The very high total precipitation during measurement year 1972-73 had little obvious beneficial effect on the plants studied. Up to 85% of the precipitation came during October through March. The resulting deep snow cover delayed initial plant growth, although once begun growth followed a relatively normal early summer pattern. A deficiency in mid and late summer precipitation apparently resulted in less total height growth in 1973 for most species than for the other 2 measurement years.

[2]*Unpublished data, Beaver Creek Watershed.*

Other Species and the Availability of Green Forb Forage

Twenty-four other species were observed and the typical phenologic stage recorded on each observation date:

Scientific names of other forb species (nomenclature follows McDougall 1973)

Symbol	Scientific name and authority	Common name
ACLA	*Achillea lanulosa* Nutt.	Western yarrow
ANPA	*Antennaria parvifolia* Nutt. (*A. aprica* Greene)	Pussy toes
ASTE	*Astragalus tephrodes* Gray.	Milk vetch
BADI	*Bahia dissecta* (Gray) Britton.	Bahia
CIWH	*Cirsium wheeleri* (Gray) Petrak.	Thistle
DAAL	*Dalea albiflora* Gray.	Indigobush; pea bush
DECO	*Desmanthus cooleyi* (Eaton) Trel.	Desmanthus
EPPA	*Epilobium paniculatum* Nutt.	Willow weed
ERUM	*Eriogonum umbellatum* Torr. (E. cognatum Greene.)	Wild buckwheat
ERFL	*Erigeron flagellaris* Gray.	Spreading flea bane
ERFO	*Erigeron formosissimus* Greene.	Fleabane, wild daisy
ERRA	*Eriogonum racemosum* Nutt.	Wild buckwheat
FEAR	*Festuca arizonica* Vasey.	Arizona fescue
GEFR	*Geranium fremontii* Torr.	Cranesbill
GIMU	*Gilia multiflora* Nutt.	Gilia
HYLU	*Hymenopappus lugens* Greene.	White-ragweed
LASE	*Lactuca serriola* L.	Wild lettuce
LOWR	*Lotus wrightii* (Gray) Greene.	Deer vetch
MEOF	*Melilotus officinalis* (L.) Lam.	Yellow sweetclover
PHWO	*Phlox woodhousei* (Gray) Nels.	Phlox
POAV	*Polygonum aviculare* L.	Knotweed, smartweed
SILO	*Sitanion longifolium* J.G. Smith	Bottlebrush squirreltail
SOMI	*Solidago missouriensis* Nutt.	Goldenrod
TRDU	*Tragopogon dubius* Scop.	Goatsbeard
VETH	*Verbascum thapsus* L.	Mullein

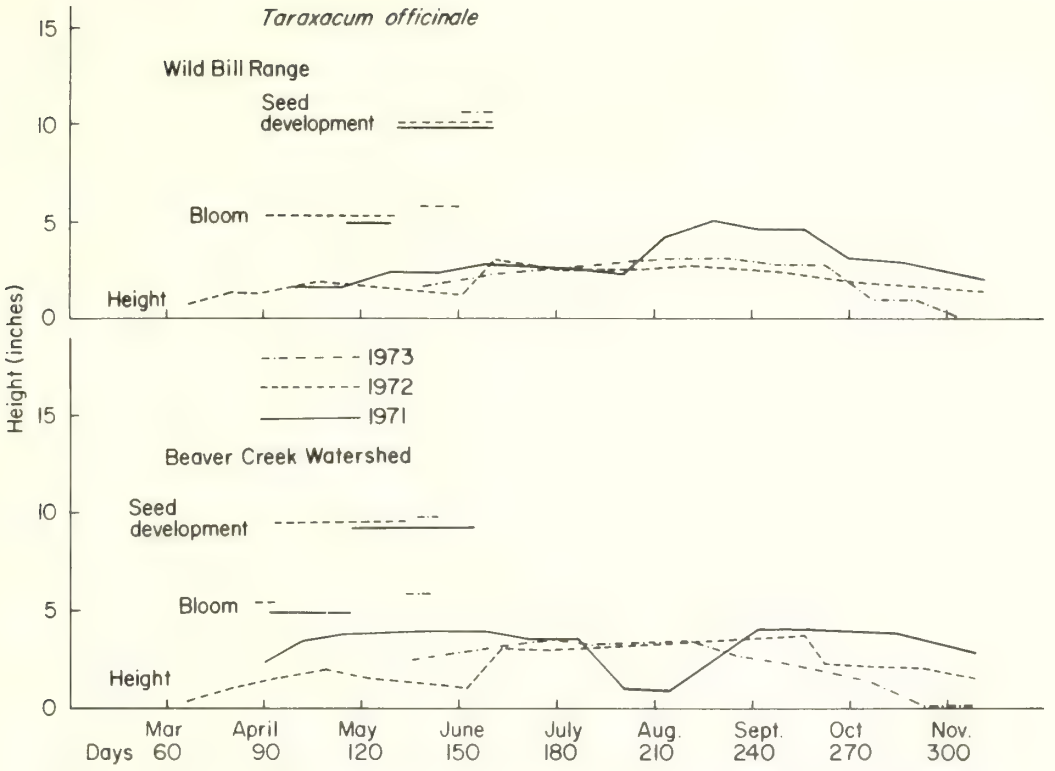


Figure 3.—Height and stage of development for *Taraxacum officinale* at the Wild Bill Range and at the Beaver Creek Watershed.

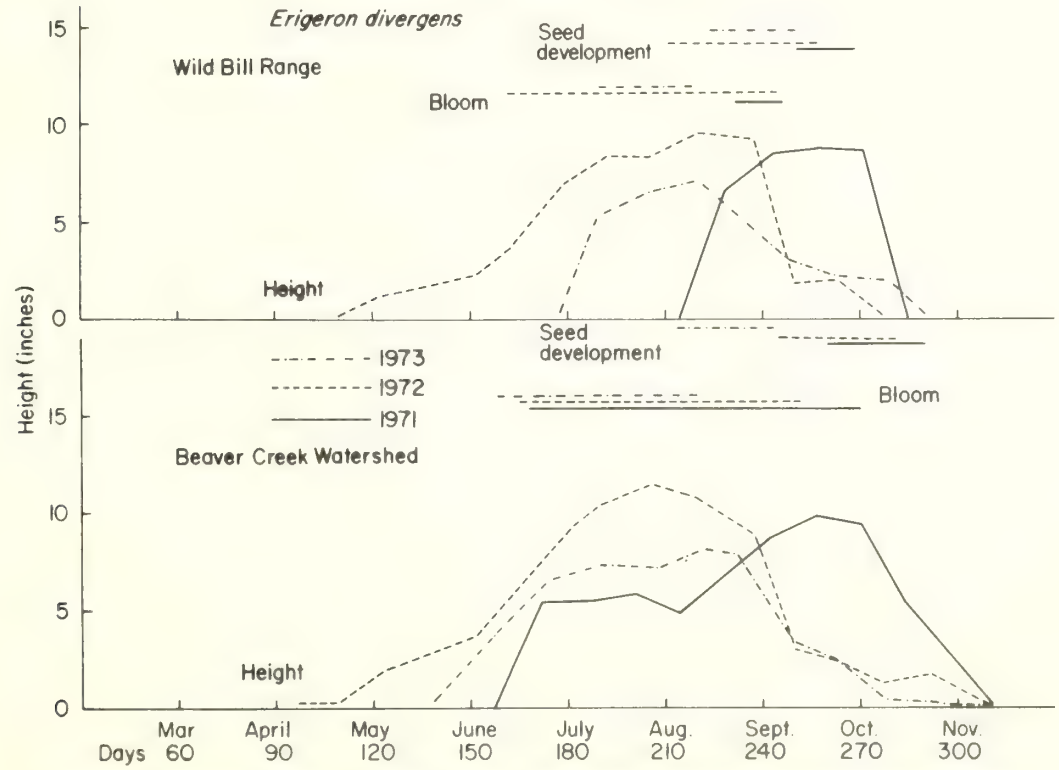


Figure 4.—Height and stage of development for *Erigeron divergens* at the Wild Bill Range and at the Beaver Creek Watershed.

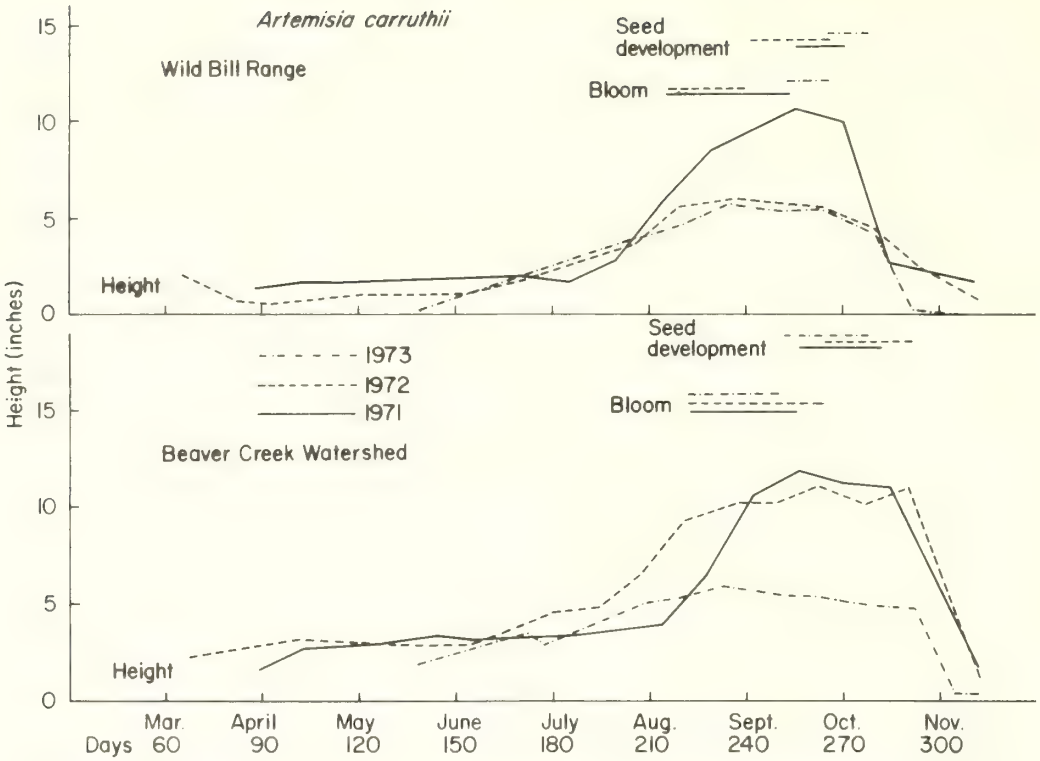


Figure 5.—Height and stage of development for *Artemisia carruthii* at the Wild Bill Range and at the Beaver Creek Watershed.

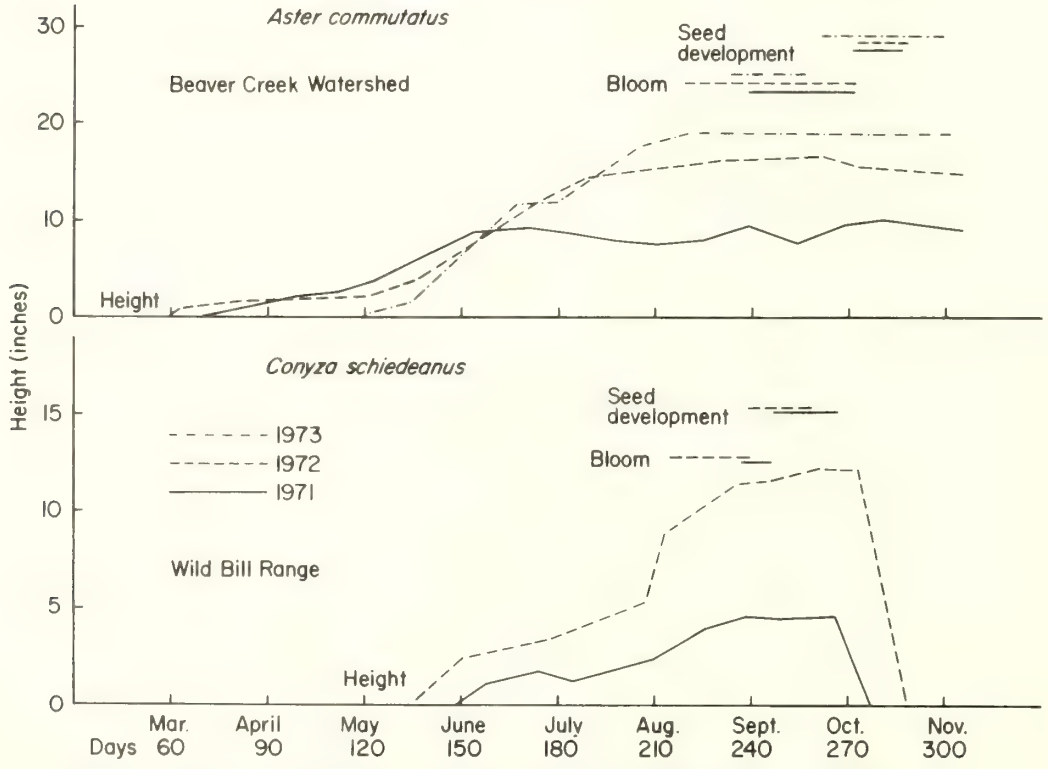


Figure 6.—Height and stage of development for *Aster commutatus* at the Beaver Creek Watershed and *Conyza schiedeanus* at the Wild Bill Range.

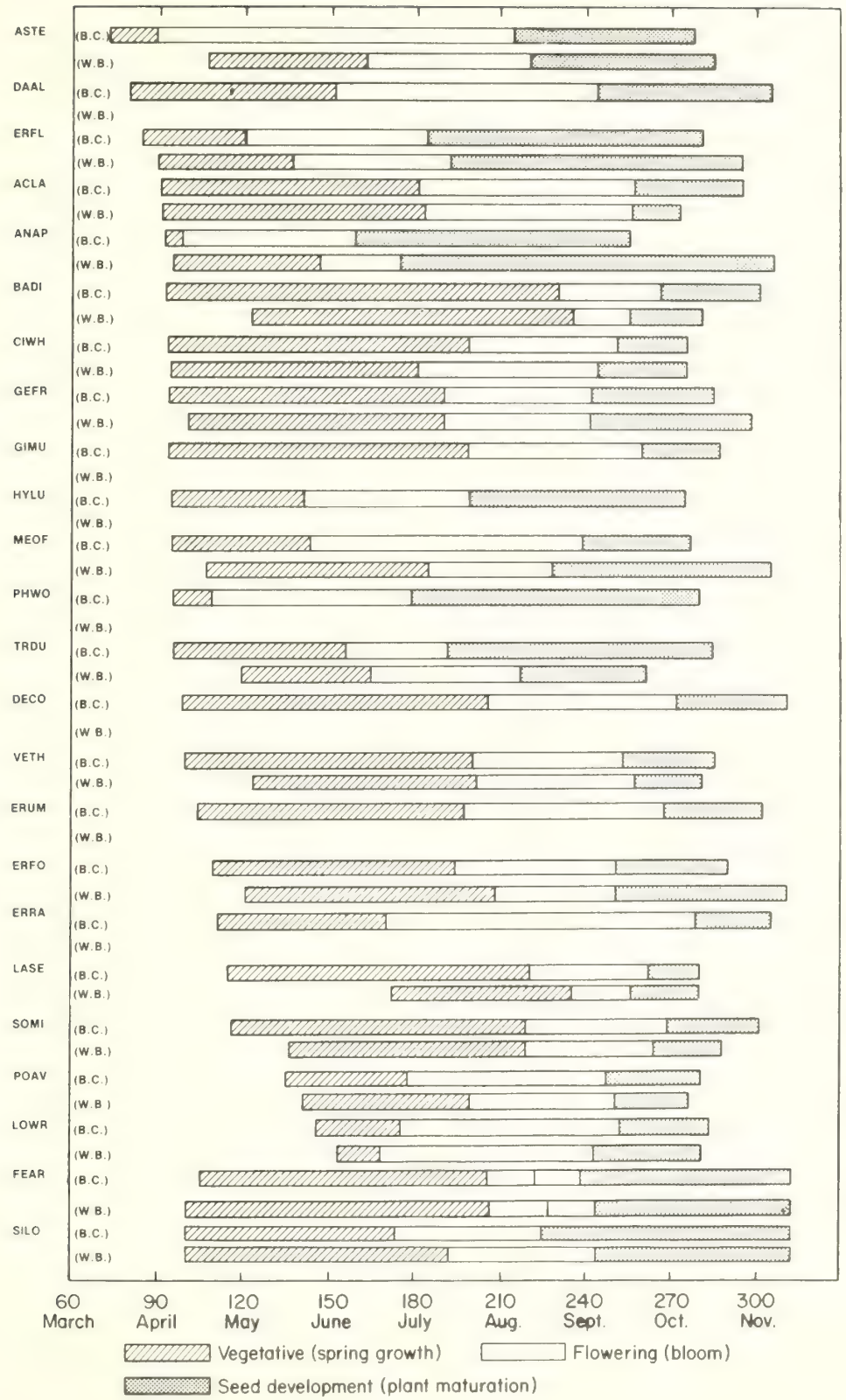


Figure 7.—Phenology of minor forbs at the Wild Bill Range (W.B.) and at the Beaver Creek Watershed (B.C.) (average of 3 years).

Knowledge of species phenology provides information on timing of forage availability and, by inference, something of the type of forage available (e.g., rosettes, leafage, and flower stalks).

A visual comparison of broad growth stages is shown in figure 7. The figure represents an average of 3 years. A sequence of new growth started over a 6-week period at both locations. In general, growth started 2 weeks later at the Wild Bill Range than at the Beaver Creek Watershed. Plants in which growth initiation varied the most between areas were goatsbeard (20 days), Missouri goldenrod (18 days), and bahia (20 days). Even greater differences occurred between areas in blooming dates of some species. Those with the greatest differences include pussytoes (47 days), milk vetch (74 days), yellow sweetclover (40 days) and knotweed (21 days).

The plant development stages illustrate a diversity of green forage palatable to deer (Neff 1974) was available throughout the growing season at both study areas.

Plant development was about 2 weeks later at the Wild Bill Range than at Beaver Creek Watershed, a much greater difference than would be expected from the elevation difference of only 600 feet. The expected difference based on Hopkins' Bioclimatic Law (Hopkins 1918) and calculated from elevation and latitude would be only 8 days, or about one-half the actual difference. The difference in mean temperature of 3.5° F is also greater than would be expected and accounts for a portion of the phenological variation between the two areas. Locations influenced by the presence of large mountains and other unknown factors may experience climatic variations accompanied by plant phenology differences, which are not directly predictable from other areas of similar elevation.

Literature Cited

Blaisdell, James P. 1958. Seasonal development and yield of native plants on the upper Smoke river plains and their relation to certain climatic factors. USDA Tech. Bull. 1190, 68 p. Washington, D.C.

Brown, Harry E., Malchus B. Baker, Jr., James J. Rogers, Warren P. Clary, J. L. Kovner, Frederic R. Larson, Charles C. Avery, and Ralph E. Campbell. 1974. Opportunities for increasing water yields and other multiple use values on ponderosa pine forest lands. USDA For. Serv. Res. Pap. RM-129, 36 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Costello, David F., and Raymond Price. 1939. Weather and plant-development data as determinants of grazing periods on mountain range. USDA Tech. Bull. 686, 30 p. Washington, D.C.

Ellison, Lincoln. 1954. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Monogr. 24:89-184.

Hopkins, A. D. 1918. Periodical events and natural law as guides to agricultural research and practice. U.S. Mon. Weather Rev. Suppl. 9:5-42.

Jameson, Donald A. 1965. Phenology of grasses of the northern Arizona pinyon-juniper type. USDA For. Serv. Res. Note RM-47, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

McDougall, Walter B. 1973. Seed plants of northern Arizona. 593 p. Museum North. Ariz., Flagstaff.

Neff, Don J. 1974. Forage preferences of trained mule deer on the Beaver Creek Watersheds. Ariz. Game and Fish Dep. Spec. Rep. 4, 61 p. Phoenix.

Pearson, Henry A., and Donald A. Jameson. 1967. Relationship between timber and cattle production on ponderosa pine range: The Wild Bill Range. 10 p. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Solbrig, Otto T. 1971. The population biology of dandelions. Am. Sci. 59:686-694.

OREST SERVICE
DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENTAL STA.
CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SCI., TECH. & AGR. DIV.

How to Use RUN WILD Data Files Stored on Microfiche

David R. Patton[1]

A computer printout of data in the RUN WILD system is contained on 28 microfiche, available by accession No. PB 296984 from the National Technical Information Service. Instructions are provided to locate specific types of wildlife information on microfiche.

Keywords: RUN WILD, wildlife data base.

In meeting the needs of National Forest System to have access to large amounts of data for writing environmental impact statements, environmental analysis reports, and developing habitat improvement projects, the Forest Service has developed a storage and retrieval system for wildlife habitat information. This system, RUN WILD, is available to biologists working in the Southwest.

RUN WILD consists of computer files with the main program written in conversational mode to allow the user to list habitat factors that are associated with each of 745 vertebrate species. The system contains three levels of information: (1) inventory, (2) species habitat associations, and (3) management data. These levels start with general information in the inventory file, and increase in detail to the management file which contains very specific data for individual species. The general RUN WILD system has been described in two previous Forest Service publications (Patton 1978, Casner et al. 1978).

In 1978, the regional Oversight Committee[2] that guides and controls the RUN WILD system decided that because of the physical size of the computer printout and difficulties encountered in charging for computer access, another method was needed to make the information available to prospective users. The simplest and least expensive method found was to have the RUN WILD printout copied onto microfiche.

Instructions for Using Microfiche

RUN WILD II is the second version of the RUN WILD data base. All printouts created prior to October 1978 should be destroyed. The entire data base has been printed on microfiche and can be obtained by requesting accession No. PB 296984 from the National Technical Information Service, U.S. Department of Commerce, 5825 Port Royal Road, Springfield, Va. 22161. This NTIS document consists of 28 numbered microfiche measuring 4 by 6 inches that can be viewed with a magnification of 20 power for easy reading. Each fiche has 63 pages in

[1]*Principal Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, located at the Station's research work unit at Tempe, in cooperation with Arizona State University. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*William D. Zeedyk (chairman) and Rogert S. Bumstead, USDA Forest Service; John Carr; Arizona Game and Fish Department; John Antonio and Edward Olson, Navajo Nation; Gerald Gates, New Mexico Department of Game and Fish; Lee Upham and Don Seibert, Bureau of Land Management; and Dick Bauman, Bureau of Reclamation.*

1	8	15	22	29	36	43	50	57
2	9	16	23	30	37	44	51	58
3	10	17	24	31	38	45	52	59
4	11	18	25	32	39	46	53	60
5	12	19	26	33	40	47	54	61
6	13	20	27	34	41	48	55	62
7	14	21	28	35	42	49	56	63

Figure 1.—Location of pages on microfiche.

7 rows and 9 columns. Pages on the fiche are numbered from 1 to 63 (fig. 1). Instructions for locating the information by subject are shown in table 1.

Both index numbers and names are used in RUN WILD to identify inventory items (vegetation types, animals, etc.) to simplify locating them in the system. For vegetation types there is also an identification number listed which is not used in the system but is a hierarchical classification number as described by Brown and Lowe (1974). Vegetation types (biome, series, and association) are listed only if there are wildlife species associated with the type. An exception is that a series (423.400, 522.300, etc.) in the hierarchy is always listed whether or not wildlife species have been associated with the type. On some microfiche there are blank spaces. These spaces are reserved for future additions of information to that section.

Literature Cited

Brown, David E., and Charles H. Lowe. 1974. The Arizona natural system for natural and potential vegetation—Illustrated summary through the fifth digit for the North American Southwest. J. Ariz. Acad. Sci. 9(3), 56 p.

Casner, Wilson B., Barbara Kulongowski, David R. Patton, and Sandra J. Pinkerton. 1978. RUN WILD—For the UNIVAC 1100 Series—Implementation and maintenance. USDA For. Serv. Gen. Tech. Rep. RM-51A, 31 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Patton, David R. 1978. RUN WILD: A storage and retrieval system for wildlife habitat information. USDA For. Gen. Tech. Rep. RM-51, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Table 1.—Location of subject information on microfiche

Category	Fiche number	Page number
Inventory		
1. List of vegetation type (284 types)	1	2-4
2. List of amphibians (Group 1 - 29 species)	1	4
3. List of birds (Group 2 - 335 species)	1	5-10
4. List of fishes (Group 3 - 105 species)	1	11-12
5. List of mammals (Group 4 - 159 species)	1	13-15
6. List of reptiles (Group 5 - 117 species)	1	16-18
7. List of counties (46 in Ariz. and N. Mex.)	1	18-19
8. List of National Forests (11 in Ariz. and N. Mex.)	1	19
9. List of key habitat factors (61)	1	19-20
Species habitat associations		
10. Animals by vegetation type		
Types with index numbers 1 - 25	1	20-63
Types with index numbers 26 - 61	2	2-63
Types with index numbers 62 - 112	3	1-63
Types with index numbers 112 - 153	4	1-51
Types with index numbers 154 - 222	5	1-62
Types with index numbers 223 - 280	6	2-62
Types with index numbers 281 - 284	7	4
11. Animals by key habitat factor		
Factors with index numbers 1 - 59	7	4-63
Factors with index numbers 60 - 61	8	1-2
12. Animals by county.		
Counties with index numbers 1 - 10	8	3-63
Counties with index numbers 10 - 20	9	1-63
Counties with index numbers 20 - 33	10	1-63
Counties with index numbers 33 - 44	11	1-63
Counties with index numbers 44 - 46	12	1-11
13. Animals by National Forest		
Forests with index numbers 1 - 9	12	12-63
Forests with index numbers 9 - 11	13	1-15
Management data		
14. Management information by group and species		
Group 1, Species 1 - 29	13	16-44
Group 2, Species 1 - 19	13	45-63
Group 2, Species 20 - 82	14	1-63
Group 2, Species 83 - 145	15	1-63
Group 2, Species 146 - 208	16	1-63
Group 2, Species 209 - 271	17	1-63
Group 2, Species 272 - 334	18	1-63
Group 2, Species 335	19	1
Group 3, Species 1 - 62	19	2-63
Group 3, Species 63 - 105	20	1-43
Group 4, Species 1 - 20	20	44-63
Group 4, Species 21 - 83	21	1-63
Group 4, Species 84 - 146	22	1-63
Group 4, Species 147 - 159	23	1-13
Group 5, Species 1 - 50	23	14-63
Group 5, Species 51 - 113	24	1-63
Group 5, Species 114 - 117	25	1-4
15. References by group and species		
Group 1, Species 1 - 29	25	5-16
Group 2, Species 1 - 168	25	17-63
Group 2, Species 168 - 335	26	1-45
Group 3, Species 1 - 80	26	45-63
Group 3, Species 80 - 105	27	1-7
Group 4, Species 1 - 159	27	7-56
Group 5, Species 1 - 28	27	57-63
Group 5, Species 28 - 117	28	1-32

ober 1979

RESEARCH NOTE RM-378

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SCI. TECH. DIV.

How to Build and Use a Light Table Camera Mount

Richard E. Francis and Roger R. Kerbs[1]

A camera mount was assembled to fit a light table stereoscope bridge. The mount allows various camera-lens combinations to be used for copying aerial photos or other remotely sensed imagery from the light table. The cost of assembly was less than $20 and 1 hour labor.

Keywords: Photographic equipment, remote sensing.

It is often necessary to copy aerial photos and other remotely sensed imagery for special uses. These uses include scale modification, slide talks, manuscript illustrations, training aids, and duplication of original material. The copying process usually involves rephotographing a specific portion of a 9- by 9-inch or 70-mm format transparency onto a smaller format such as 35-mm transparencies or negatives. The copying process can be performed by commercial photo labs, but the process is time consuming, expensive, and direct control over the quality and area copied is lacking.

Hand held or tripod mounted cameras are unsteady or awkward, and the copy photos are usually not sharply focused and not properly aligned. The camera copy mount described here eliminates those problems, is inexpensive, allows maximum area and format selection, is easy to construct, and is used directly on a light table.

[1]*Associate Range Scientist and Range Technician, respectively, Rocky Mountain Forest and Range Experiment Station. Central headquarters is at Fort Collins, in cooperation with Colorado State University.*

Design and Assembly

The camera mount described is designed to fit a Richards 918 LW light table stereoscope bridge (fig. 1).[2] It can be adapted to fit most light tables with similar features.

[2]*Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

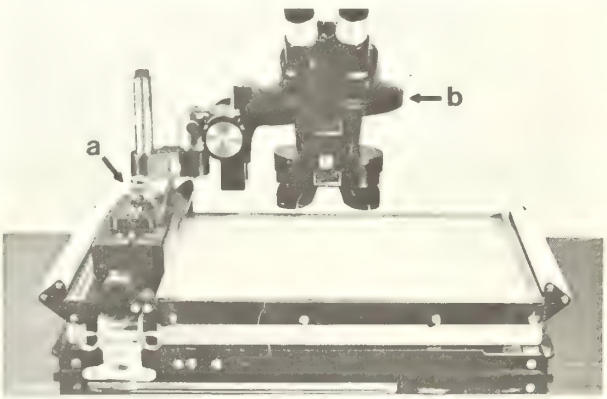


Figure 1.—Light table with stereoscope bridge (a) and stereoscope (b) in place.

The mount was constructed by inserting a 5/8-inch-diameter by 12-inch-long cold-rolled steel rod into the clamp link of the bridge assembly which normally accepts the stereoscope (fig. 2). A 1/8-inch-diameter hole was drilled through the center of the rod 3 inches from one end. A cotter pin was inserted into the 1/8-inch hole and used as a stop against the clamp link. The cotter pin stop eliminates the rod from sliding through the clamp link far enough to strike the glass surface of the light table.

A sliding binocular support was clamped to the 5/8-inch rod. This support can be placed at any desired height. The clamp link which holds the rod can also be adjusted to different camera heights and angles on the stereoscope carriage assembly post.

A 1/4-inch by 20-thread by 5/8-inch stud inserted permanently in a ball and socket head (fig. 2) results in a head connector that will mount most cameras. The ball and socket was then attached to the sliding binocular support to complete the camera mount. Vertical adjustment of the camera on the rod and horizontal movement of the stereoscope bridge on the light table provides camera-to-subject alignment. The apparatus was assembled in 1 hour at a cost of less than $20. Parts were purchased from local hardware and photographic stores.

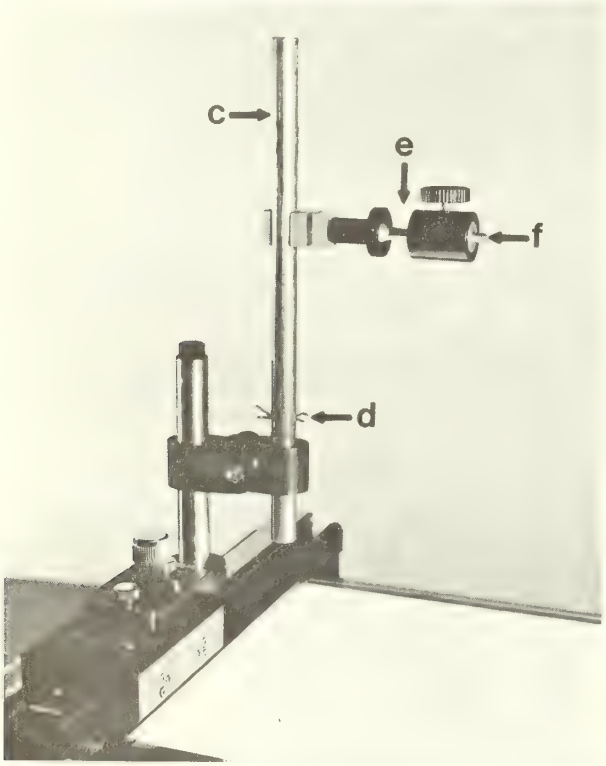


Figure 2.—Stereoscope replaced with camera mount which includes: steel rod camera support (c), cotter pin stop (d), camera ball and socket head (e), and camera attachment stud (f).

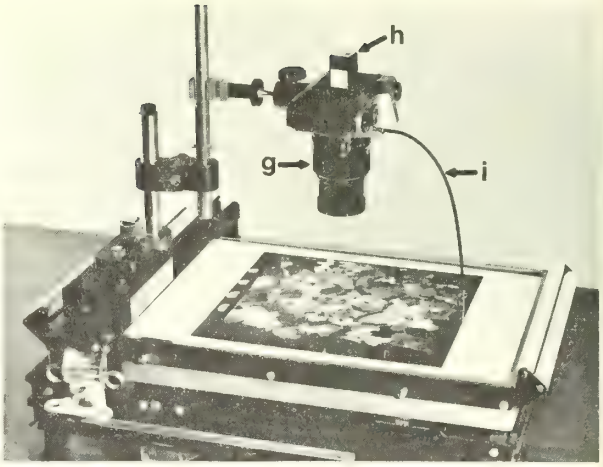


Figure 3.—A 35-mm camera with macro lens (g) attached to the light table camera mount; note level bubble (h) and shutter release cable (i). Image on the light table is a 9- by 9-inch transparency.

Application and Discussion

The camera mount and light table can be used to copy single or spooled transparencies. Using the proper camera-lens combination, 35-mm to 9- by 9-inch formats can be copied (fig. 3). Entire frames or specific portions of frames may be copied on appropriate format films.

Best results have been obtained by using a light table that approximates mean daylight (5,000° K) and color film rated accordingly. This is especially critical when copying color or color infrared originals. Using this light source and copy film combination, the camera mount provided color copies with minimal color shifts. Color may shift when copying extremely dense originals which require copy camera shutter speeds slower than 1/15 second. To avoid imaging the light table fluorescent tubes, camera shutter speed should not be faster than 1/30 of a second. The use of a shutter release cable adds to the sharpness of the copy photos by minimizing camera vibrations.

Depth-of-field is critical when copying at close distances. Camera-to-subject alignment affects depth-of-field and edge-to-edge sharpness of the resultant copy photo. Use of a macro lens and a small aperture allows extremely close and sharp copies. The macro lens is a flat-field lens that minimizes edge distortion. A small bubble level on the camera is used to make critical camera alignments to maximize depth-of-field and edge sharpness. A glass plate placed over the photo to be copied keeps it flat and increases photo copy sharpness. Overhead lights should be turned off to eliminate reflections on both the photo and the glass.

ember 1979

RESEARCH NOTE RM-379

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SO. TECH. CORR. DIV.

Recovery Potential of Fire-Damaged Southwestern Ponderosa Pine

John H. Dieterich[1]

The survival potential of fire-damaged ponderosa pine is dependent on many factors, including season when the fire occurs, percentage of crown scorch, and consumption of live crown material. Other factors influencing survival include site conditions, available growing season moisture, and incidence of insect attacks.

Keywords: Fire damage, fire effects.

Management Implications

Ponderosa pine (*Pinus ponderosa* Laws.) damaged by dormant-season fires frequently show remarkable signs of recovery during the first growing season following the fire. The unnecessary removal of crop trees or potential crop trees could be prevented if a method were developed to allow those doing the salvage marking to distinguish between killed or badly damaged trees and trees having a good chance for survival.

Nearly all aspects of predicting fire damage in southwestern ponderosa pine need additional study before a final set of guidelines can be prepared. Nevertheless, some observations can be made that should help in predicting whether given trees should be removed in salvage cutting or remain as growing stock.

[1]*Principal Research Forester, Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Tempe, in cooperation with Arizona State University. Station's headquarters is at Fort Collins, in cooperation with Colorado State University.*

Figure 1.—Average scorch height of about 25 feet was measured on this clump of trees burned early on the morning of November 2. The clump is near sample area No. 1.

General

1. Season of fire occurrence and degree of crown scorch or consumption are of primary importance in predicting damage and mortality.
2. Extent of cambium damage is also important but is difficult to assess.
3. When residual growing stock is important, a two-stage marking system may have application. During the first entry, mark only those trees for removal that are obviously dead or dying; follow up with a second marking to remove trees that have subsequently died or that need to be removed because of form, spacing, etc.
4. Trees that survive past the second growing season have survived the most critical period.
5. Removal of a large percentage of live crown by scorching can result in reduced growth the first year. Growth should return to normal during the second and third growing seasons.

Dormant-Season Fires

1. To improve the tree selection process, delay marking fire-damaged trees until after growth has started in the spring.
2. If scorch height is 90% or more of live crown, mark for removal.
3. If crown consumption is observed on trees that are scorched more than 80%, mark for removal.

Growing-Season Fires

1. If salvage marking can be delayed until after the start of the next growing season without causing unacceptable decline in wood quality in dead trees, the damaged tree selection process will be improved.
2. If the above delay is feasible, mark according to instructions for dormant season fires.
3. If marking cannot be delayed, all trees with crown scorch greater than 70% should be removed. If crown consumption is observed, mark tree for removal regardless of percentage of crown scorch. (Conclusion based in part on information from other studies.)

Introduction

Marking fire-damaged trees for salvage following wildfire is at best an uncertain operation. Trees that have been burned so badly they are essentially dead after the fire front has passed are easily identified, and it is relatively simple to identify trees that have sustained little or no damage from fire. The marginal trees are difficult to identify—those trees that have sustained considerable damage but may yet survive.

Future development of the stand and its ability to recover and produce acceptable amounts of wood fiber depend on the ability of the timber marker to select which trees to cut and which to leave. There are few guidelines available to help the timber marker decide which trees to cut and which to leave as he inspects for visible fire damage (Herman 1954, Lynch 1959, Wagener 1961). Prematurely removing sapling and pole-size trees that have been damaged but not killed has the dual effect of removing potential crop trees and eliminating an important seed source needed to regenerate the stand naturally.

The study described here and a study by Rietveld (1976) were prompted by the observation that many fire-damaged trees were showing remarkable signs of recovery during the first growing season following a November wildfire. Severely scorched trees were putting on new growth, and cones that had developed the previous year were continuing to develop to maturity. The objective of this study was to supplement existing knowledge concerning survival of fire-damaged ponderosa pine, with an ultimate goal of eventually developing guidelines for more accurate marking of timber salvage operations. In addition, this note reviews some of the factors that are important in gaining a better understanding of fire damage, and demonstrates how a description of fire characteristics can be used to more accurately interpret fire damage.

Literature

Rietveld (1976) studied cone and seed development on the same study area described in this paper. He concluded that seedfall from foliage-scorched trees represented an important seed source for naturally regenerating the area and that, while cone size, seed soundness, and seed weight were markedly less in severely scorched trees, trees with crowns scorched as much as two-thirds produced viable seed. Nelson (1952) found that pine needles were killed almost instantly when exposed to temperatures of 147° F, whereas at 125.6° F they withstood 9-11 minutes of heat. Hare (1961) indicated that the lethal temperatures for some 20 species of plants varied from 113° to 139° F. This explains in part why damage occurs more readily when air temperatures are high—less heat is required to raise the ambient air to a lethal temperature. It also explains why scorch is minimized during cold weather. Byram (1958) recognizes air temperature and vegetation temperature as being important and uses the following example as an illustration of their relationship.

> "On a cold day when temperature is 4° C (39° F) a fire heats the needles of a pine to 102° C (216° F). The crown would thus be completely scorched. However, the buds with their higher heat capacity might be heated to only 38° C (100° F) and would remain undamaged. On a hot day when the initial vegetation temperature is 32° C (90° F) the needles of a similar tree could be heated to the same temperature 102° C (216° F) by a somewhat lower intensity fire. In this case the buds might reach a temperature of 64° C (147° F) because of their initial high temperature. Hence, two different fires, one of which was relatively cool on a hot day and the other relatively hot on a cool day may result in equal amounts of crown scorch. But the former may do considerably more damage to the trees than the latter because it should produce greater injury to the heavier parts of the tree such as the buds and cambium tissue. Thus crown scorch is not always a reliable indication of total damage."

Herman's studies (1950, 1954) of fire-damaged ponderosa pine resulted in the preparation of a simple guideline for marking trees for salvage following a growing-season fire (the Fort Valley Fire of July 1948). In preparing the marking guide, Herman identified two factors as particularly significant: (1) length of live crown killed by fire, expressed as percent of total crown length, and (2) fire intensity (not quantified) in the vicinity of the tree. He recommended two rules of thumb based on 6 years of observation and measurement: (1) removal of all trees with more than 60% of the length of live crown killed by fire; and (2) marking for removal all trees with 51-60% of

length of live crown killed if the fire in the vicinity of the tree was a heavy ground fire or a combination ground and crown fire. Herman suggested special attention should be given to trees of poor vigor because even relatively slight damage to these trees may be sufficient to cause their death.

Dormant-season fire studies by Wagener (1955, 1961) indicate bud kill, which is related to the season in which the fire occurs, is much more important than foliage kill in determining survival chances. He reported on physical changes that help in evaluating damage: twigs on which the needles are still present but show a "set" in an abnormal position—usually bent in the direction of the run of the fire—are also certain to be dead. On the other hand, if when using field glasses it is possible to see green bases on a portion of the needles, those twigs and branches, and possibly those nearby in other trees, are likely to be alive, regardless of whether or not all show green needle bases. Distinguishing between live and dead twigs becomes much easier after a few months have elapsed because dead needles are shed from the live twigs and branches, whereas the needles are retained for a longer period of time on the dead twigs and branches. The reason for these differences is that on living twigs and branches abcission layers continue to form releasing the dead needles; on dead twigs and branches growth stops and there is no new formation of the abcission layer. Wagener continues with the observation that, "... if no needles have been burned off or only those on a few lower branches, and if the greater part of the foliage on the trees hangs in a natural position, the percentage of live buds and twigs is likely to be high even though not much green foliage is evident." He recognized season, tree age, site, and extent of bud damage as being most important and noted there is a general tendency to overestimate mortality in cruising or marking a burn after a fire.

Lynch (1959) reported on a study of tree mortality from a July (growing season) wildfire in young ponderosa pine on the Colville Indian Reservation, Washington. He concluded that mortality was directly related to the percent of crowns "burned" and that virtually all the mortality occurred during the first 2 years following the fire. He found that small trees suffered greater mortality than large trees having the same degree of burn; that trees in the 6- to 9-inch d.b.h. class having more than 50% crown injury suffered temporary reduced diameter growth; and that height growth of the surviving trees was not affected by burning.

The effects of an early growing season wildfire on growth and survival of young ponderosa pine were studied by Pearson et al. (1972) on an area where a thinning study was in progress. The fire essentially destroyed an unthinned stand (basal area 126 square feet per acre) while an adjacent stand thinned to 20 square feet per acre was relatively undamaged. Following the fire, Pearson et al. selected 30 trees with crown damage in the range of 0-100% and, using increment borings, measured growth rates during three periods: (1) prior to thinning; (2) after thinning; and (3) after the fire. Radial growth increased on burned trees where crown scorch was less than 60% and, at least temporarily, decreased where crown scorch was more than 60%. Some growth was recorded on trees with percent of crown scorch up to 95% but it was below even the pre-thinning growth rate.

Fire Description

The Burnt Fire provided an opportunity to study the effects of a dormant-season fire on tree survival and growth in ponderosa pine. The fire started on the Mt. Eldon District of the Coconino National Forest, Arizona, and burned 7,150 acres between November 1 and 4, 1973.

A more complete description of the fire in terms of burning conditions, fuels, and fire intensity is needed to better understand the effects the fire had on the stand.

Weather

Weather on the fire was characterized by unusually strong winds (60 miles per hour) and temperatures ranging from about 25° F during the night to 55° F during the day.

Relative humidity was lower than normal during the week prior to the November 1 fire start, but minimum relative humidities recorded during the fire were not unusually low—in the 25-35% range.

The fire area was essentially without precipitation during September and October, only 0.03 inch being recorded. Only 1.25 inches of rainfall had fallen in August. Normal for these 3 months totals 7.13 inches making a deficiency of nearly 6 inches of rainfall. This moisture deficiency was reflected in the degree to which large fuels were consumed by the fire.

Rainfall records for the 4 years following the fire indicate a slight rainfall deficiency during the growing season for 1974 and 1975; near normal conditions in 1976; and above normal during the 1977 season. Total rainfall for the year was slightly below normal in 1974 and an equally small amount above normal during 1975 and 1976. Growing-season precipitation was well above normal in 1977. These records indicate rainfall amounts during the four growing seasons following the fire should have been adequate to provide a satisfactory environment in terms of available moisture for tree recovery and growth.

Fuels

Much of the area had been logged—some of it during the past 10 years. Some thinning had also been done in the area. Fuel treatment following these activities would be considered adequate in terms of present standards. Onsite fuel inventories were not available prior to the fire, but a reasonable estimate of fuel loading, based on measurements in similar stands following fuel treatment might be as follows:

Fine Fuels: litter, twigs, branches less than 3 inches diameter, grass and herbaceous material; 5 tons per acre.

Large Fuels: Branches and woody material greater than 3 inches diameter; 7 tons per acre.

Of this 12 tons per acre total, approximately 2-2.5 tons per acre of the lighter material was consumed in the moving fire front. Residual burning probably consumed an additional 5-6 tons per acre.

Fire Behavior

Intensity.—Rates of spread were difficult to reconstruct, but onsite observations indicated that for short periods of time, within major runs, the fire spread at rates approaching 1.25 miles per hour. Average rates of spread, however, were more in the neighborhood of one-fourth to one-half mile per hour.

Table 1 summarizes an assumed set of fuel, weather, and fire behavior parameters for November 2 on the Burnt Fire. Using these parameters, three additional values have been computed that characterize fire intensity—all of them useful in predicting and interpreting fire effects.

1974

1975

1976

19

Figure 2.—Tree No. 578 experienced 80% crown scorch and some crown consumption was observed on the lower branches. In the 1977 photo the tree shows a 60% reduction in length of live crown with 12 feet of live crown remaining.

974

1975

976

1977

Figure 3.—Tree No. 579 was scorched on 95% of the crown. Length of live crown was reduced by 53% leaving approximately 14 feet of live crown when the 1977 photo was taken. Evidence would indicate that this tree should have been marked for removal, but it has since recovered, and growth is normal.

Table 1.—Synopsis—Weather, fuel and fire characteristics, Burnt Fire, November 2, 1973

	Daytime conditions		Night conditions
Estimated or measured	*High*	*Extreme*	
Air temperature	50° F	50° F	35° F
Wind velocity (20-ft standard)	30 mi/h	40 mi/h	20 mi/h
Available fuel[1]	2.5 tons/acre	2.5 tons/acre	2.0 tons/acre
Rate of spread	40 chains/h 0.73 ft/sec	90 chains/h 1.65 ft/sec	20 chains/h 0.366 ft/sec
Computed			
Byram's fireline intensity	672 Btu/ft/sec	1518 Btu/ft/sec	270 Btu/ft/sec
Flame length	9 ft	13 ft	6 ft
Scorch height	8 ft	14 ft	5 ft

[1]The amount of fuel consumed in the fire front.

Byram's Fireline Intensity is a quantification of the heat released per unit of length of fire edge, per unit of time. As points of reference, most prescribed fires should be below 100 Btu/ft/sec; wildfires that exceed 500 Btu/ft/sec are reaching fire intensities that preclude direct attack, and above 1,000 Btu/ft/sec major runs are likely. Flame length is directly related to fireline intensity and can be used to help predict height of crown scorch, which in turn can be used to assess the impact of the fire on individual trees and stand development. These fire intensity measures, or indicators, are further described by Albini (1976). Formulas for computing each of them are included.

Damage.—Damage from this fast-spreading fire was extremely variable ranging from complete destruction of crown material in patches of saplings and pole timber and an occasional mature tree, to large areas where the only evidence of fire was a blackened litter layer and slight scorch on the lowest portions of the crowns. Much of the stand was open-grown, and tree crowns extended to within 4-5 feet of the ground.

Strong winds and cool temperatures were responsible for average scorch heights below what might be expected with warmer air temperatures and lower wind velocities. For example, the group of trees in figure 2 has an average scorch height of about 25 feet. The computed scorch height (table 1, extreme daytime conditions) is considerably lower than the observed. This difference emphasizes the need for additional validation studies, and for getting accurate on-site wind measurements. If the wind velocity were reduced from 40 to 30 miles per hour and all other conditions remained the same, scorch height would have been computed to be 21 feet—reasonably close to the observed 25 feet.

Methods

A tree damage assessment study was undertaken starting in September 1974, 10 months after the fire. Twenty-five trees were selected at two locations approximately 1 mile apart. Both sites were burned over in the early stages of the fire, and the trees appeared to have been exposed to fires of roughly the same intensities. The trees selected showed at least 75% crown scorch; some showed partial crown consumption, and all were within the d.b.h. range of 6-14 inches. No attempt was made to assess the extent of cambium damage during the first inspection in 1974. Notes were made on fire scars as they became evident during subsequent visits to the site. Percent of crown scorch was determined, and the trees were photographed from a photo point, so that subsequent photos could be used to show changes in the general condition of the tree. The trees were rephotographed in September 1975, 1976, and 1977, and observations were recorded concerning the general condition of the tree, persistence of dead needles, presence of insects, cone development, and, of course, if the tree had died.

Results and Conclusions

The factors that influence the ability of the individual trees to survive the effects of fire, include (1) percent of crown scorch and/or crown consumption, (2) extent of cambium damage, (3) season in which the fire occurs—which in turn influences plant physiology, (4) presence of insects, and (5) rainfall during the growing seasons following the fire.

Figures 2, 3, and 4 illustrate graphically the changes that occurred in crown development on three sample trees following this November wildfire. The photographs were taken at 1-year intervals starting in September 1974, 10 months after the fire.

Results of these observations indicate the following:

Of the 25 trees tagged for observation, 6 trees (24%) were dead at the end of the fourth growing season. Two of these died between the 1974 and 1975 observations; three died between the 1975 and 1976 observations; and one additional tree died between the 1976 and 1977 observations.

Fire scars were detected on two of the trees during the 1975 observation. No other cambium damage was apparent during subsequent visits to the sites.

Some crown consumption was noted on 7 of the 25 trees. Of the six trees that were dead after the 1977 growing season, some crown consumption had been noted on four of them. Three trees that experienced crown consumption have since survived, apparently because they suffered no more than 90% crown scorch. Tree No. 578 (fig. 2) was one of the seven trees on which crown consumption was observed. It had 80% crown scorch and has since recovered completely.

By the end of the second growing season (1976) there was a 50-70% reduction in length of live crown. By the end of the 1977 growing season, bases of live crowns were averaging 16 feet above ground level and crowns were

continuing to develop normally. Prefire crown base levels averaged 5-6 feet above ground.

Needle persistence was variable but most dead needles had fallen by the second observation, 23 months following the fire. Probably more than 80% of the needles dropped off during the second winter following the fire.

In September 1977, three growing seasons after the fire, increment cores were taken from each of the living sample trees. Two-thirds of the trees had a slightly suppressed growth ring the first year following the fire but by the second and third years were growing at or above the prefire growth rate; two of the trees showed a reduced growth rate for the three seasons. The remaining trees showed growth rates that were normal or above normal for the three growing seasons.

Literature Cited

Albini, Frank A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. Gen. Tech. Rep. INT-30, 92 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Byram, George M. 1958. Some basic thermal processes controlling the effects of fire on living vegetation. U.S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn., Res. Note 114, 2 p. Asheville, N.C.

Hare, Robert C. 1961. Heat effects on living plants. U.S. Dep. Agric., South. For. Exp. Stn., Occas. Pap. 183, 32 p. New Orleans, La.

Herman, F. R. 1950. Survival of fire-damaged ponderosa pine: A progress report. U.S. Dep. Agric., For. Serv., Southwest. For. and Range Exp. Stn., Res. Note 119, 3 p. Tucson, Ariz.

Herman, F. R. 1954. A guide for marking fire-damaged ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 13, 4 p. Fort Collins, Colo.

Lynch, Donald W. 1959. Effects of a wildfire on mortality and growth of young ponderosa pine trees. U.S. Dep. Agric., For. Serv., Intermt. For. and Range Exp. Stn., Res. Note 66, 8 p. Ogden, Utah.

Nelson, Ralph M. 1952. Observations on heat tolerance of southern pine needles. U.S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn., Stn. Pap. 14, 6 p. Asheville, N.C.

Pearson, H. A., J. R. Davis, and G. H. Schubert. 1972. Effects of wildfire on timber and forage production in Arizona. J. Range Manage. 25(4):250-253.

Rietveld, W. J. 1976. Cone maturation in ponderosa pine foliage scorched by wildfire. USDA For. Serv. Res. Note RM-317, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Wagener, Willis W. 1955. Preliminary guidelines for estimating the survival of fire-damaged trees. U.S. Dep. Agric., For. Serv., Calif. For. and Range Exp. Stn., Res. Note 98, 9 p. Berkeley, Calif.

Wagener, Willis W. 1961. Guidelines for estimating the survival of fire-damaged trees in California. U.S. Dep. Agric., For. Serv., Calif. For. and Range Exp. Stn., Misc. Pap. 60, 11 p. Berkeley, Calif.

1974

1975

1976

197

Figure 4.—The left side of the crown of tree No. 594 was scorched nearly to the tip by convective heat. Although the crown has lost some if its symmetry, it still contains more than 18 feet of live crown material. Note recovery of the two smaller trees in left side of the photo.

ember 1979

RESEARCH NOTE RM-380

CLEMSON UNIVERSITY LIBRARY
MAR 24 1980
SCI., TECH. & AGR. DIV.

OREST SERVICE
S DEPARTMENT OF AGRICULTURE
CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Method for Collecting Soil-pupating *Rhyacionia* Pine Tip Moths

Daniel T. Jennings[1] and Milton J. Stelzer[2]

Plastic foam cups filled with soil and placed beneath infested shoots are used to collect soil-pupating *Rhyacionia.* The pupation cups are inexpensive, easily installed, and easily removed for rearing pupae, pupal parasitoids, and adult moths.

Keywords: *Rhyacionia neomexicana,* pine tip moth collecting technique, insect rearing, parasitoids.

Introduction

Studies on *Rhyacionia* pine tip moths often require collection of cocoons. This is difficult in the case of soil-pupating species because the cocoons are small, fragile, and may be lost to predation before they are collected. For example, mice dig cocoons of the southwestern pine tip moth, *R. neomexicana* (Dyar), at the bases of infested seedlings and feed on both larvae and pupae (Jennings 1975).

The collection technique described here, which employs plastic foam cups, was developed and successfully used at Chevelon, Ariz., with *R. neomexicana* (Dyar) and *R. jenningsi* Powell. The technique should also work with other species having similar habits (i.e., pupating at the bases of infested trees attached to the bole). The cups are useful for collecting pupae, rearing pupal parasitoids, and rearing adult tip moths. Other uses include (1) determining when larvae descend tree boles (cups are inspected hourly or daily and larvae removed before pupation), (2) determining the period or duration of larval descent, (3) investigating the processes of cocoon formation and pupation, and (4) measuring the effects of predation indirectly by exclusion.

[1]*Entomologist, Northeastern Forest Experiment Station, USDA Building, University of Maine, Orono. Previously at the Rocky Mountain Forest and Range Experiment Station, Albuquerque; Station's headquarters is at Fort Collins, in cooperation with Colorado State University.*

[2]*Entomologist, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, Oreg.*

Materials and Equipment

The materials and equipment needed to install the cups, collect the cocoons, and rear pupal parasitoids and adult tip moths include the following:

Plastic foam cups, 6-8 ounce
Wire, 24 gauge, light duty
Calipers
Knife or razor blade
Wire cutters
Hand pliers
Trowel
Waterproof ink marker
Pencil or pen
Insect forceps
Hand pruners
Masking tape
Nylon screening, fine mesh
Rubber bands

Method

The collecting method consists of (1) locating infested shoots before the larvae leave the shoots, and (2) attaching plastic foam cups filled with soil beneath the shoots (fig. 1). Descending larvae bore into the cup soil and pupate against the tree bole (fig. 2). The larvae chew shot holes in the tree bark and mix exuding resins with silk to form cocoons. The cocoons are easily collected by disassembling the cup and removing the soil.

Installation

Cups are easily installed by following the procedures illustrated in figure 3 and described below:

1. Locate infested shoot (fig. 3A).
2. Remove needles below shoot and measure stem diameter with calipers (fig. 3B).
3. Mark cup bottom and cut out hole; slit bottom across diameter (fig. 3C).
4. Extend slit up one side of cup to rim (fig. 3D).
5. Open cup and place around stem (fig. 3E).
6. Wire shut and fill cup with soil (fig. 3F).

Locate infested shoots in the field prior to the time larvae leave the shoots and descend tree boles for pupation. For the southwestern pine tip moth in Arizona, pupation begins in early July and is generally completed by mid-August (Jennings 1975). Inspection of damaged shoots will indicate the presence or absence of larvae; fresh mammal diggings around root collars may also indicate cocoons are being formed. Damaged shoots are easily recognized in mid-summer by their short, stubby needles and generally brown, withered appearance. Mined shoots turn reddish brown, dry, and become brittle. Accumulations of frass and sparse silk webbing are usually evident.

To facilitate cup installation, remove needles below infested shoots for a distance of 15-20 cm. Measure stem diameters with calipers at about the level for installed cups, or slightly higher to allow a tight fit. Mark measured diameters in the center of cup bottoms with intersecting lines and cut holes with a single edge razor blade. Then cut slits from two opposing corners of the hole to the cup sides, forming a continuous slit across the bottom diameter of the cup. Extend one slit up one side of the cup to the rim. Take care not to slit the opposing side, otherwise the cup will break into halves. Cups can now be partially opened and placed around tree stems below infested shoots.

Figure 1.—Plastic foam cup below infested terminal shoot.

Figure 2.—Cocoons of *Rhyacionia neomexicana* attached to tree bole. Note shot hole below center cocoon.

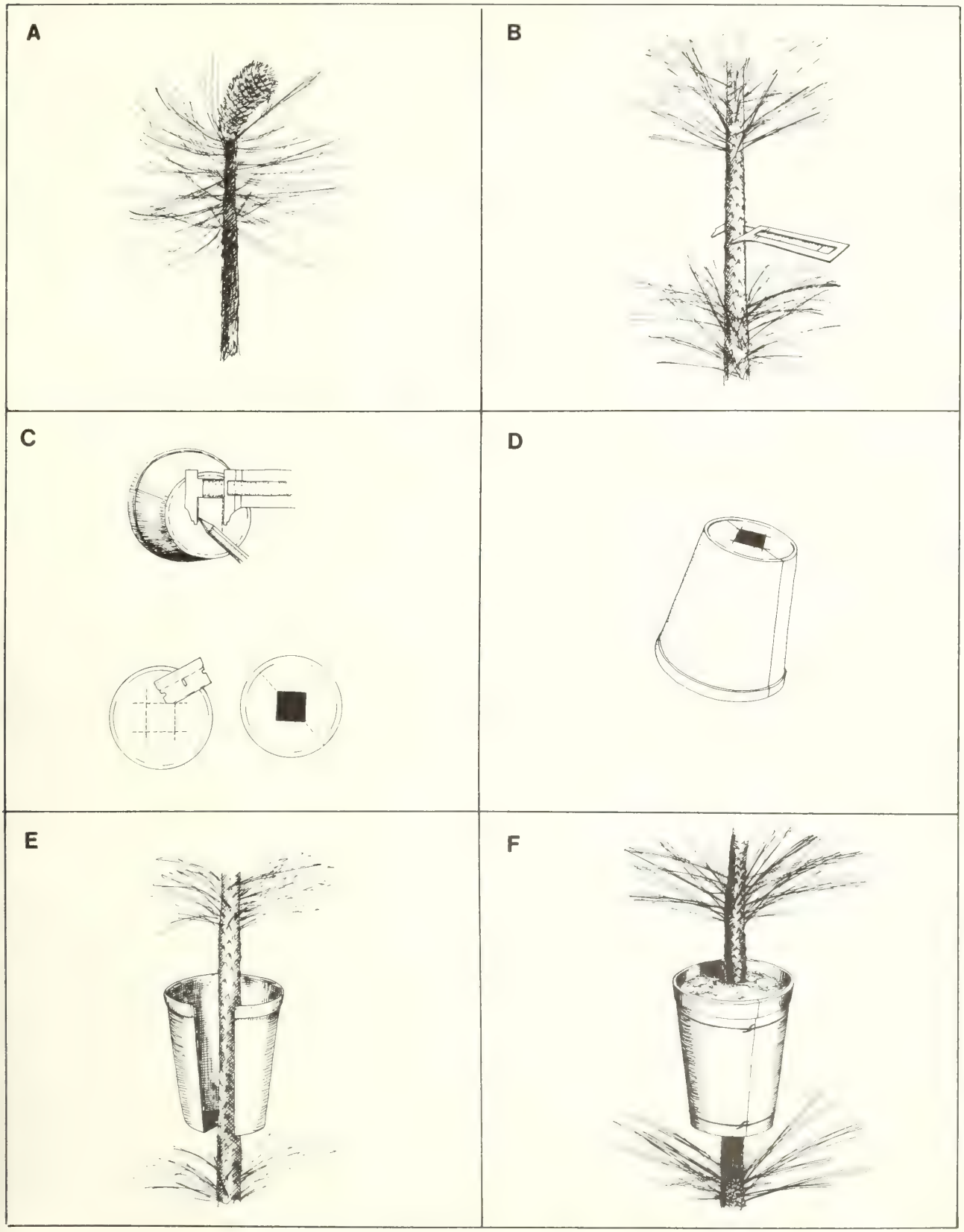


Figure 3.—Procedure for installing cups (see text).

Place two wires around the circumference of each cup, one near the bottom and one near the top. Soft, light-duty steel wire works best. Wires are twisted tight with pliers and excess ends trimmed with wire cutters. Tightening the wires closes the cup and forms a seal between the cup and tree bole.

Fill cups to about 1 cm of the top with loose sandy soil free of rocks, sticks, and other debris. Soil can be sifted prior to installation and placed in a bucket for storage and transportation. Or, dig soil near bases of infested trees and place directly into the cups. Hand trowels are excellent for digging soil and filling cups. Use waterproof markers to permanently number and mark cups for data reference.

Collection and Rearing

Leave cups in the field until all larvae have left the shoots, usually by early August for *R. neomexicana*. Two methods have been used for collecting pupae from cups. The easiest and least destructive method is to cut fastening wires and remove the cup and soil from the tree bole. The cocoons usually remain attached to the tree and can be removed gently with forceps. Occasionally, some pupae detach and are found in the ring of soil that was nearest the tree. Place collected pupae in vials or cartons for rearing.

A more destructive method, but one that simulates natural conditions by leaving cocoons attached, is to cut the tree stem above and below the cup and remove the cup intact. Place masking tape over the hole in the cup bottom to retain soil and tree stem. Transport cups, upright, to the laboratory and disassemble or place in an insectary for rearing pupal parasitoids and adult moths. To retain emerging insects, place fine nylon mesh screening over the cup tops and secure with rubber bands.

Parasitoids of *R. neomexicana* pupae collected at Chevelon were reared in the laboratory from these pupation cups. In the field, cups were placed beneath infested shoots in early July, retrieved after pupation had ceased in late July and early August, and held at room temperature (about 20° C) in the laboratory until September or October. Cups were inspected daily (5 days per week) and emerging parasitoids collected and preserved in 70% ethanol. For rearing spring-emerging parasitoids and adult tip moths, cups were stored in a walk-in cooler (4-5° C) from September/October to February/March, when they were again held at room temperature. Emerging parasitoids were processed as before; adult moths were killed and pinned. In this manner, collections and rearings were made of both summer/fall and spring-emerging parasitoids of *R. neomexicana*, and of spring-emerging moths.

Discussion

The pupation cups are relatively inexpensive, easily installed, and easily disassembled or removed. Pupae are concentrated along the tree bole in an easily accessible place, apparently free of mammal predation. The necessity for digging around root collars is eliminated; hence, pupae are less likely to be damaged.

In studies at Chevelon, elk and deer occasionally nibbled cups or tore them from trees. This problem can possibly be eliminated by painting cups a dark color; however, damage was encountered too infrequently to warrant the extra time and expense of painting. In windswept areas some soil may be dumped from cups and, in extreme cases, cups may be completely emptied. Sand is more apt to be windblown than a mixture of sand, loam, and clay. Coarse-textured soils should be used for filling cups if available; however, remove rocks and debris.

The pupation cups described in this paper were used to collect and rear pupae of *R. neomexicana* and *R. jenningsi* in Arizona. They may also be useful for collecting pupae of *R. adana* Heinrich, *R. zozana* (Kearfott), and perhaps *R. bushnelli* (Busck). *R. adana* pupates on the root collars of red pine, *Pinus resinosa* Ait.; jack pine, *P. banksiana* Lamb.; and Scots pine, *P. sylvestris* L. (Martin 1960). Stevens (1966) reported that *R. zozana* pupates around the bases of ponderosa pine, *P. ponderosa* Laws., at ground level. Apparently *R. bushnelli* "drops" from infested tips of various pines and pupates at or just below ground level (Swenk 1927). Similar cups may be useful for investigating the pupation habits of other soil-pupating insects.

Literature Cited

Jennings, Daniel T. 1975. Life history and habits of the southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar) (Lepidoptera:Olethreutidae). Ann. Entomol. Soc. Am. 68:597-606.

Martin, J. Lynton. 1960. Life history of the pine tip moth, *Rhyacionia adana* Heinrich, in Ontario (Lepidoptera:Olethreutidae). Can Entomol. 92: 724-728.

Stevens, Robert E. 1966. The ponderosa pine tip moth, *Rhyacionia zozana*, in California (Lepidoptera:Olethreutidae). Ann. Entomol. Soc. Am. 59:186-192.

Swenk, M. H. 1927. The pine tipmoth in the Nebraska National Forest. Nebr. Agric. Exp. Stn. Res. Bull. 40, 50 p. Lincoln, Nebr.

Mountains Southwest Plains

Research Note RM-381

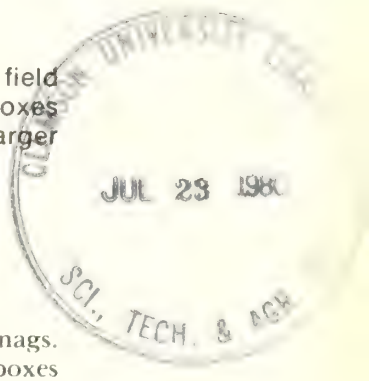
January 1980

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Constructing Wooden Boxes for Cavity-Nesting Birds

Howard L. Gary and Meredith J. Morris[1]



Construction details for two sizes of nest boxes are described. In field trials, eight species of cavity-nesting birds nested in the smaller boxes and five species, in addition to red squirrels, raised young in the larger nest boxes.

Keywords: cavity-nesting birds, nest boxes, birdhouses

Management Implications

Nest boxes will never replace natural cavities found in live trees and snags. However, when few or no trees with natural cavities are available, nest boxes can help meet cavity requirements and help maintain diversity and populations of cavity-nesting birds.

Introduction

The scarcity of nesting and roosting cavities is a major factor limiting the populations and diversity of primary cavity-nesting birds (woodpeckers) and secondary cavity-nesting birds (those using old woodpecker holes).[2] An average of two or three nesting trees per acre is needed to maintain diversity and populations of secondary cavity-nesting birds in southwestern ponderosa pine (*Pinus ponderosa*) forests (Balda 1975, Scott 1978) (fig. 1). Past commercial timber harvesting practices and increasing demand for fuelwood in national forests of the central Rocky Mountains, especially along the Front Range in Colorado, have reduced the number of nesting trees (American Forests 1979).

When nesting trees are scarce, nest boxes can supplement or substitute for natural nest cavities. Studies by Hamerstrom et al. (1973) with American kestrels (*Falco sparverius*), and Zeleny (1973) with eastern bluebirds (*Sialia sialis*) demonstrated an increase in breeding when suitable boxes were provided. Bruns (1960) and Franz (1961) cite several European works that document a fivefold to tenfold increase of insectivorous cavity-nesting birds after nest boxes were introduced.

This note describes construction of two sizes of wooden nest boxes and their use by birds and mammals in Colorado Front Range ponderosa pine forests. Design of the boxes was adapted from various features of existing box plans (Sawyer 1955, Peterson 1963, U.S. Department of Interior 1969, and Zeleny 1977) (table 1).

Nest Box Design and Placement

Entry hole sizes shown in table 1 restrict use to selected species or similar-sized birds. Starlings (*Sturnus vulgaris*), for example, cannot enter boxes with holes smaller than 1-1/2 inch in diameter. Entry holes 3 inches in diameter are recommended for common flickers (*Colaptes auratus*), for example, but this size hole does not prevent use by smaller species, such as mountain bluebirds (*Sialia currucoides*).

Nest boxes should be placed on posts or trees and secured with nails or wire. Boxes generally should face the nearest trees, shrubs, fences, etc., so that birds on their first flight may reach a perch high enough to provide protection against predators. Boxes in trees should be in the more open areas within the crown so birds can easily find them.

[1] *Principal Hydrologist and Principal Wildlife Biologist, respectively, Rocky Mountain Forest and Range Experiment Station. Central headquarters is at Fort Collins, in cooperation with Colorado State University.*

[2] *Beebe, Spencer B. 1974. Relationships between insectivorous hole-nesting birds and forest management. Unpublished manuscript, 49 p. Yale University, School of Forestry and Environmental Studies, New Haven, Conn.*

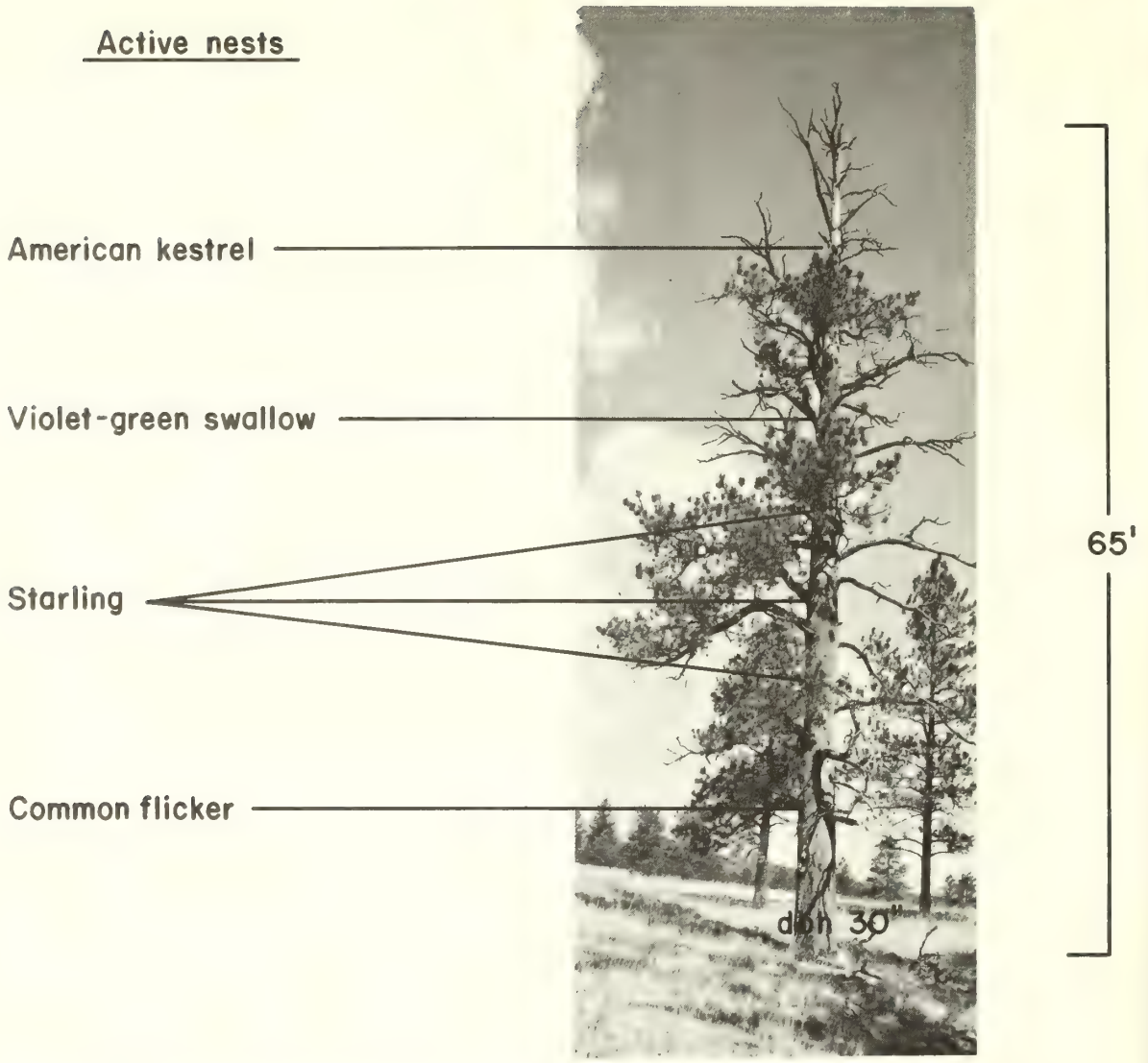


Figure 1.—High quality nesting trees are rapidly disappearing from accessible areas along the Front Range in Colorado.

Boxes to accommodate western bluebirds (*Sialia mexicana*) should be placed along forest edges or in grassy glades within open forests. Kestrels prefer to nest in open areas because of their hunting habits. Boxes should be accessible from the ground or by ladder to allow inspection, cleaning, and minor repairs.

Nesting material should not be provided in the small-floor-size box (table 1) since most species using these boxes build their own nests. The large-floor-size nest box (table 1), intended for larger species which do not build nests, should have 1/2 to 1 inch of wood shavings. Old nests should be removed and boxes cleaned each fall to reduce fouling and parasites.

Two to four small nest boxes per acre are recommended. This density will prevent most intraspecies and interspecies conflicts for territorial right (Sawyer 1955). One large nest box per 10 acres is recommended if the objective is to attract the larger, less common birds, such as American kestrel, flammulated owls (*Otus flammeolus*), and saw-whet owls (*Aegolius acadicus*). These species are generally less affected by removal of nesting trees (Balda 1975).

Some nest boxes are never used by resident birds, perhaps because plentiful natural nesting sites are available elsewhere, boxes are not found, entrance holes are too small, boxes are placed too high or low, predators are present, or construction is faulty. However, western and mountain bluebirds were found to accept large nest boxes with 3-inch entry holes at locations 20 feet above ground when there were no other nesting sites. Kind, size, and placement of nest boxes should be based on nest requirements of specific species. A nest box not used its first season may be used the next year.

Nest Box Construction

Two nest boxes, designated small and large, were designed as acceptable, durable, and relatively inexpensive substitutes for natural cavities.

Table 1.—Dimensions (inches) and placement of nest boxes acceptable by selected cavity-nesting birds in the Front Range in Colorado (adapted from Sawyer 1955, Peterson 1963, and U.S. Department of the Interior 1969)

Species	Floor size	Box depth	Entry hole diameter	Feet above ground
Mountain chickadee (*Parus gambeli*)	[1]4x5-1/2	6 to 8	1-1/8	5 to 10
House wren (*Troglodytes aedon*)	"	"	1-1/4	"
Violet-green swallow (*Tachycineta thalassina*)	"	"	1-1/2	"
Tree swallow (*Iridoprocne bicolor*)	"	"	"	"
Downy woodpecker (*Dendrocopos pubescens*)	"	8 to 10	1-1/4	"
Pygmy nuthatch (*Sitta pygmaea*)	"	"	"	"
Red-breasted nuthatch (*Sitta canadensis*)	"	"	"	"
White-breasted nuthatch (*Sitta carolinensis*)	"	"	1-1/2	"
Western bluebird (*Sialia mexicana*)	"	"	"	"
Mountain bluebird (*Sialia currucoides*)	"	"	"	"
Hairy woodpecker (*Dendrocopos villosus*)	[2]6x7-1/2	12 to 16	"	10 to 25
Saw-whet owl (*Aegolius acadicus*)	"	"	2-1/2	"
Common flicker (*Colaptes auratus*)	"	"	3	"
American kestrel (*Falco sparverius*)	"	"	"	"
Common screech owl (*Otus asio*)	"	"	"	"

[1]*Standard 1- by 6-inch boards for floor and walls, actual size variable from board to board.*
[2]*Standard 1- by 8-inch boards for floor and walls, actual size variable from board to board.*

Both boxes can be constructed from 1-inch redwood or pine. Lumber grades no. 2 and no. 3 planed or rough one side are suitable. Drilled pilot holes for nails are necessary if splitting is a problem. Loose knots and minor splitting can be patched with small blocks of wood or sheet metal. The wood should weather naturally to blend with surrounding vegetation.

Materials and dimensions for the nest box sizes are shown in table 2. Variable board widths are satisfactory if all box components are cut from the same board. Depending on condition of the lumber and expected waste, length of box wall components in table 2 can be shortened 1 inch to fit various standard board lengths. For example, shortened wall, bottom, and lid components for a large nest box can be cut from an 8-foot-long board, or for two small boxes from a 10-foot-long board.

Box components are most easily cut with a table saw (for bevel cuts), radial arm saw (for straight and angle cuts), and a drill press (circle cutter for entry holes.) The 1-1/2- and 3-inch-diameter entry holes are centered 2 and 3 inches below the top of the front wall of the small and large boxes, respectively. An electric hand drill fitted with a high-speed 1-1/2-inch-diameter wood bit or hole cutter may be used to make the small entry hole.

Boxes can be assembled with simple hand tools after components are cut and entry holes made (fig. 2). Assembly of the small box is similar.

A few preconstruction tasks should be completed before assembly. A pencil line is drawn about 4 inches down from one end of the back board (fig. 2A). The line is needed to position the sides at the top of the box. Next, drill 1/8-inch-diameter holes about 1-1/2 inches down and in from the edge on each end of the back board (fig. 2A). A third hole is also drilled between the holes at each end of the back board. These holes are used to attach the box to a tree or fencepost. Two or three vents and/or lighting holes (3/8- to 1/2-inch diameter) should be drilled about 1 inch below the top of both side boards (fig. 2A). The final preconstruction task is to scratch or roughen the inside of the box front with a wood chisel or saw (fig. 2B). The roughened surface serves as an escape ladder for fledglings. A strip of hardware cloth stapled to the inside front serves the same purpose. In the large nest box, a small block of wood (2 by 2 by 2 inches) nailed halfway down on the inside front board will serve as a ladder and inside perch.

Illustrated step-by-step construction is presented in figure 2. First, attach the sides to the back board. Place the long edge of each side, in turn, flush with the pencil line, align with the edge of the back board, and nail using three to five sixpenny box nails (fig. 2A).

The bevel on the box front is then aligned with the slope of the sides (fig. 2C). One nail is set on each side near the top. This makes it possible to apply leverage to align

Table 2. Materials and approximate dimensions of components for small and large nest boxes

Materials	Small box	Large box
	- - *(inches)* - -	
Lumber for box (standard dimension)	1x6x62	1x8x96
Front (length)[1]	10	17
Back (length)	17	24
Sides, cut on diagonal (total length)	20-1/2	34
Long edge	11	18
Short edge	9-1/2	16
Lid[2]	10	13
Bottom[3]	4-1/8	5-7/8
Lumber for lid cleats (1- by 2-inch board)	9	19-1/2
Lid holding cleat (length)[4]	5-1/2	7-1/4
Lid under cleat (length)	3-1/2	5
Lid outside cleat (length)	—	7-1/4
Hardware	- - *Amount* - -	
Nails (sixpenny box)	18-20	26-30
Round-head stove bolts, nuts (3/16 inch)		
For lid hinge (1 inch long)	4	4
For lid holding cleat (2 inches long)	2	2
Washers (3/16 inch)	8	8
Loose pin butt hinge (2 inches)	1	1
Screw eyes for latch (3/4 inch)	2	2
Galvanized wire for latch (12 gage)	10 inches	10 inches
Nail for latch (eightpenny box)	1	1
Double-headed nails to secure box on post or tree (sixteenpenny)	4	6

[1]15° bevel edge (suggested) top of front wall. Bore 1-1/2- or 3-inch entry holes for small and large boxes, respectively.

[2]15° bevel edge (suggested) for lid contact against back wall.

[3]Cut to fit inside box walls (exact size dependent on board width). Cut one-fourth-inch triangle from each corner for drainage holes.

[4]15° bevel edge (suggested) for contact with lid.

either side with the front. Three or four additional nails to each side are adequate to secure the box front.

The box bottom should be carefully measured and sawed for a snug fit (fig. 2D). Remove a one-fourth-inch triangle from each corner to allow drainage. Recess the bottom board about one-fourth-inch to prevent weathering and secure, using one or two nails on each side.

The lid is constructed by nailing two 1- by 2-inch cleats (cut to size shown in table 2) to the underside of the lid board (fig. 2E). The cleats minimize warping and splitting and prolong life of the box lid.

The lid-holding cleat is next attached to the box (fig. 2F). With the box lying on its back, position the lid on top of the box with the beveled edge against the back board. The beveled edge of the lid-holding cleat is then placed and held in contact with the lid and back board. Draw a pencil line against the upper edge of the cleat to mark this position. Remove the lid from the box and realign the lid-holding cleat with the pencil line and nail to the back board using small finishing nails or brads. Then drill two 3/16-inch holes 1-1/4 inches from each end of the cleat, and through the back board. Attach the cleat to the back board using 3/16- by 2-inch stove bolts, nuts, and washers, and remove excess length of bolts with a hack-saw or boltcutter.

Many types of latches, fasteners, hinges, posts, pins, screws, etc. can be used to secure lids to nest boxes. A loose-pin butt hinge and wire fastener was used here to secure the removable lid. With the box on its back, position the lid under the lid-holding cleat and in contact with the box front. A space of about one-sixteenth inch should remain between the lid and box back (shimmed with a nail) to allow easier closing during wet weather. The butt hinge (with pin in place) is then centered above the entry hole and held in contact with the underside of the lid and box front (fig. 2G). Scribe the location of the holes in the hinge half against the box front with a pencil or awl. Scribe the position of two holes in the upper hinge half after attaching the bottom half of the hinge. Drill 3/16-inch holes at the scribed locations and attach the hinge using 3/16- by 1-inch stove bolts, nuts, and washers (fig. 2G). Remove and discard the loose pin holding the hinge halves together. Slight adjustments can be made by repositioning one side of the hinge if the hinge halves do not mesh smoothly. A metal cutting file may also be used to improve the mesh of the hinge halves.

The nest box lid is secured with a wire pin inserted through the hinge halves. The pin device is shown in figures 2H and I. The fastener is made from a straightened, 10-inch piece of 12-gage galvanized wire shaped and bent to an approximate right angle with about 3-1/2 inches on the side and a one-half inch square eye on one end. Two pairs of heavy-duty pliers for bending the wire and a wire cutter to remove excess wire are the only tools needed to make the fastener. A hammer and a hard metal surface may also be used to further straighten the finished fastener. Extra standard size fasteners should be made to replace any that are lost.

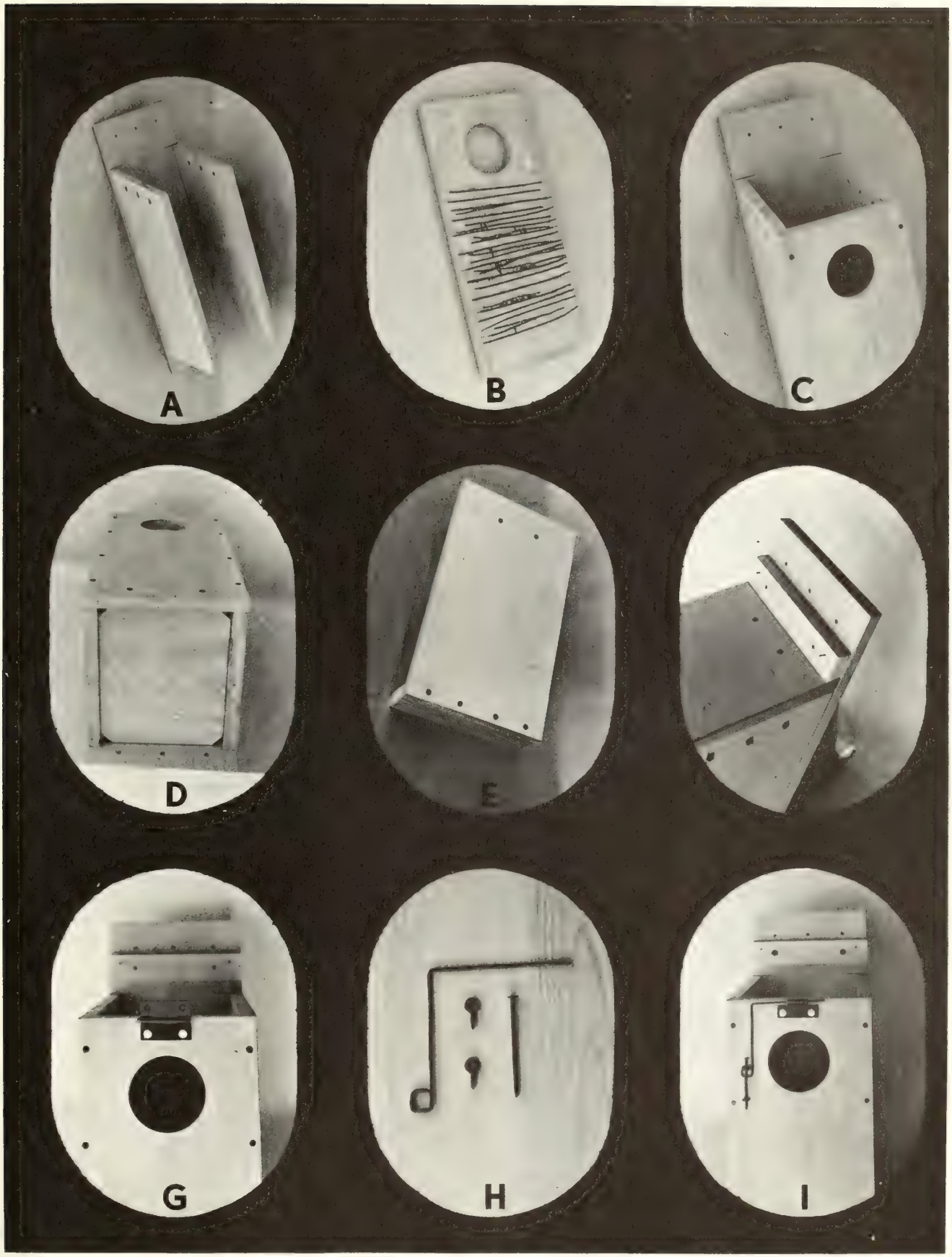


Figure 2.—Construction details for the large nest box.

With the fastener in place, either left or right side of the hinge, set the first screw eye about 1 inch from the edge of the front wall in the center of the square eye. Set the second screw eye about 1-1/2 inches directly below the first. Position both screweyes horizontally. Insert an eight-penny box nail from the top through the screw eyes to provide a lock for the fastener. Finished models of the small and large nest boxes are shown in figure 3.

Use of Nest Boxes

Nest boxes placed in large open areas within the Colorado Front Range ponderosa pine forests most commonly attract western and mountain bluebirds (fig. 4). In a recently logged ponderosa pine stand with few natural cavities on the Manitou Experimental Forest about 30 miles northwest of Colorado Springs, Colo., 100 small nest boxes were placed 5 feet above ground at densities ranging from two to six boxes per acre. These nest boxes, made for bluebirds, were similar in dimensions to the small box, but had lids secured with

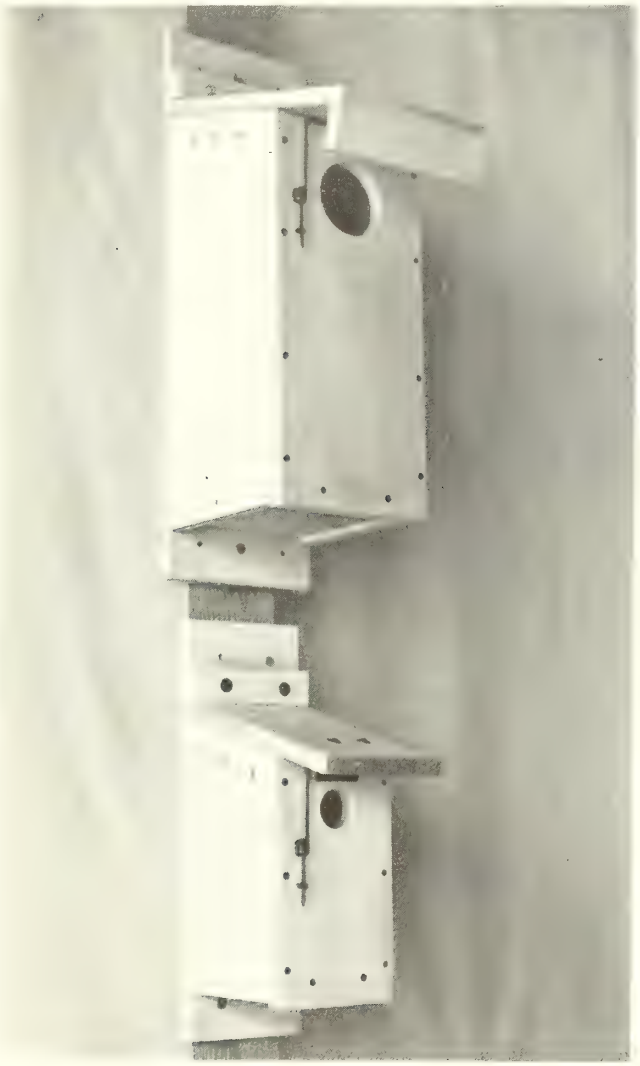


Figure 3.—Completed models of the small and large nest boxes.

Figure 4.—Small nest boxes in open ponderosa pine forests are commonly accepted by bluebirds.

screws. Box lids attached with loose-pin butt hinge and wire pin closures described in this note are much faster to remove and longer lasting than screw lid equipped boxes. During a 2-year period, the 100 boxes were used by 103 breeding pairs of cavity nesters.[3] The following birds fledged young:

Species	Breeding pairs fledging young	
	Number	Percent
Western bluebird	70	68.0
Mountain bluebird	12	11.6
House wren	10	9.7
Violet-green swallow	4	3.9
White-breasted nuthatch	3	2.9
Mountain chickadee	2	1.9
Pygmy nuthatch	1	1.0
Tree swallow	1	1.0
Total	103	100.0

[3]*Unpublished data on file, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

Five small boxes constructed as described in this note were placed at the same height, density range, and in the same area as the 100 boxes. The first year these boxes were used by two pairs of western bluebirds and one pair each of mountain bluebird, violet-green swallow, and white-breasted nuthatch.

Thirty of the large nest boxes with 3-inch entry holes placed 20 feet above ground and greater than one-fourth mile apart in open to dense old-growth ponderosa pine and mixed conifer forests with some natural cavities have been used by western and mountain bluebirds, tree swallows, common flickers, American kestrels, and red squirrels (*Tamiasciurus hudsonicus*) (fig. 5).

Figure 5.—An American kestrel feeding young in a large nest box.

Literature Cited

American Forests. 1979. Stocking the nations woodstoves. American Forests 85:19, 42.

Balda, Russell P. 1975. The relationship of secondary cavity nesters to snag densities in western coniferous forests. U.S. Department of Agriculture, Forest Service, Southwestern Region, Wildlife Habitat Technical Bulletin 1, 37 p. Albuquerque, N. Mex.

Bruns, H. 1960. The economic importance of birds in the forest. Bird Study 7(4):193-208.

Franz, J. M. 1961. Biological control of insect pests in Europe. Annual Review of Entomology 6:183-200.

Hamerstrom, Frances, Frederick N. Hamerstrom, and John Hart. 1973. Nest boxes: An effective management tool for kestrels. Journal of Wildlife Management 37(3):400-403.

Peterson, Roger T. 1963. Bird houses and feeders. National Audubon Society Circular 29, [n.p.] New York, N.Y.

Sawyer, Edward J. 1955. Bird houses, baths, and feeding shelters: How to make and where to place them. Cranbrook Institute of Science Bulletin 1, fifth edition, 36 p. Bloomfield Hills, Mich.

Scott, Virgil E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. Journal of Forestry 76(1):26-28.

U. S. Department of the Interior, Fish and Wildlife Service. 1969. Homes for birds. Bureau of Sport Fisheries and Wildlife Conservation Bulletin 14, 18 p. (revised)

Zeleny, Lawrence. 1973. Help the bluebird. National Parks and Conservation 4:13-17.

Zeleny, Lawrence. 1977. Build your own bluebird nesting box. National Geographic 151:864.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-382

February 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

A New Gila Topminnow Locality in Southern Arizona

John N. Rinne, Bryce Rickel, and Dean Hendrickson[1]

A new Gila topminnow (Atheriniformes:Poeciliidae) locality discovered in an intermittent stream on the Coronado National Forest should be protected from future mineral and water mining, off-road vehicles, grazing, and the introduction of nonnative fish species if it is to persist in this desert environment.

Keywords: endangered species, *Poeciliopsis occidentalis occidentalis*

CLEMSON UNIVERSITY LIBRARY
JUN 17 1980
SCI., TECH & AGR. DIV.

Management Recommendations

A number of actions could be taken to both maintain and expand a newly discovered population of Gila topminnow, *Poeciliopsis occidentalis occidentalis*, in Redrock Canyon on the Coronado National Forest. Since the area is grazed by domestic livestock, fencing of 150 to 200 m of stream channel may be desirable to maintain both the Gate Spring and Redrock Ranch subpopulations. Mining has long been practiced in the area, and exploratory bore holes were observed in Redrock Canyon. The reach of stream above and within the area inhabited by the Gila topminnow should be protected from any negative impacts from future mining operations, including water mining (groundwater pumping for irrigation or domestic supply). A stock tank at the headwaters of Redrock Canyon and other impoundments within the area should be resurveyed to determine the abundance and distribution of the mosquitofish, *Gambusia affinis affinis*. This competitive species should be removed from the drainage. Vehicular travel on a primitive road up the stream channel to Gate Spring should be prohibited in the reach of stream containing topminnows.

The endangered status of this diminutive native fish species should stimulate continued efforts both to maintain natural populations and to reintroduce it into suitable habitats within its natural range. Existing documents delineate such actions (Rickel 1979) and, in light of the fact that only one other population of the Gila topminnow occurs on federal lands, the Redrock system presents an excellent opportunity to accomplish both maintenance and introduction activities. During summer when topminnows will normally become abundant in this system and if adjacent springs maintain suitable surface water, gravid female topminnows could be transplanted on an experimental basis and monitored to insure perpetuation of the species and expansion of its range.

[1]*Rinne is Fisheries Biologist, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Tempe, in cooperation with Arizona State University. Station's headquarters is at Fort Collins, in cooperation with Colorado State University. Rickel is Fisheries Biologist, Coronado National Forest, Tucson, Ariz. Hendrickson is a Graduate Student, Arizona State University, Tempe.*

Past Population Discoveries

Although the Gila topminnow was once one of the most common, low desert, native fish species in Arizona, it became greatly reduced in both range and number (Minckley et al. 1977), resulting in its designation as an endangered species (U.S. Department of the Interior 1976). It now occurs naturally in only seven localities—six in the Santa Cruz River drainage and one along the Gila River near Bylas. Four localities are on private land, and one each is on Indian reservation, state, and Bureau of Land Management lands.

Despite several extant introduced populations, attempts to reestablish this livebearer in its native range have met with little success (Minckley 1969). This is related to factors such as geographic location of introduction sites, permanence of surface waters and vagaries of flooding, and the presence of nonnative fishes, principally mosquitofish.

Two of the localities—Bylas Springs (Johnson and Kobetich 1968) and Cocio Wash (Contantz 1979)—were discovered within the last decade. More recently in the San Pedro River Valley, an eighth natural population was eliminated by man through water mining within a few months of discovery (McNatt 1979).

The New Population

We first observed topminnows in Redrock Canyon in winter 1978, although they had been reported in this intermittent stream as early as the late 1960's. Water temperature was 5° C, and only a few fishes were observed in a mainstream pool. It was assumed they represented stock from a more permanent upstream habitat. Initial attempts to locate such a habitat were in March 1979 by personnel from Arizona Game and Fish Department, Arizona State University, and the USDA Forest Service. No topminnows were discovered at that time.

On May 8, 1979, the second author observed Gila topminnows in a side-channel pool (10 by 2 m; 0.5 m deep; elevation 1,348 m) downstream from Redrock Ranch, and about 0.2 km upstream from a 2-m bedrock waterfall (fig. 1). The pool was thickly overgrown with aquatic vegetation. Air temperature (36° C) exceeded water temperature (22° C) on that day, and pH was 7.5. No fish were observed in the adjacent mainstream; however, topminnows (mostly young-of-year) were abundant there in early July 1979.

Several springs in and adjacent to Redrock Canyon (e.g., Cottonwood Springs; fig. 1) were examined on May 18-19, but no fishes were sighted. These should be re-examined for topminnow during summer when populations normally become abundant because of the species' prolific reproductive capacity.

During the late May visitation, Gila topminnows were collected by electrofishing from a 150-m reach of mainstream adjacent to and below Gate Spring (fig. 1). The total population, presumably reduced by harsh winter conditions (i.e., cold weather and high runoff) was estimated to be less than 100 fish. Five voucher specimens were preserved (federal permit PRT-8-238-C).

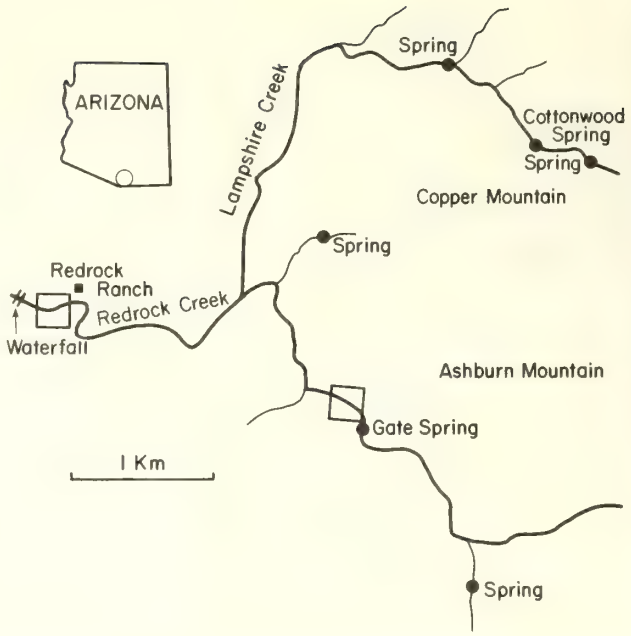


Figure 1.—Map of Redrock Canyon indicating the reaches of stream containing Gila topminnow (boxes) and other springs in the drainage system.

Selected habitat parameters were measured (see tabulation below) in the area of Gate Spring (1,395 m elevation). The area was characterized by a channel of bedrock and numerous inflowing seeps (fig. 2). Water in one side-channel, elevated spring (fig. 3) was very hard and high in conductance. Water in the mainstream (discharge 0.44 m^3 per minute) was less than one-third as hard and only one-half as saline. Water temperatures ranged from 14° C (7:00 p.m.) to 24° C (1:00 p.m.). The stream was 1 to 2 m wide, with riffles seldom exceeding 15 cm and pools 30 cm deep. There were extensive algal mats (fig. 4).

Selected physico-chemical characteristics of Redrock Creek below Gate Spring and of an unnamed elevated side-channel spring were as follows:

Physical-chemical factor	Spring	Stream
CO_2	60 mg/1	40 mg/1
Specific conductance	2,300 mmhos	1,200 mmhos
Ca^{++} hard (as $CaCO_3$)	1,050 mg/1	350 mg/1
Mg^{++} hard (as $CaCo_3$)	150 mg/1	170 mg/1
Total hard (as $CaCO_3$)	1,200 mg/1	520 mg/1
Total alkalinity (as $CaCO_3$)	170 mg/1	200 mg/1
pH	7.4	8.5

Topminnow occupied areas of algal mats almost exclusively, particularly retreating there upon our approach to the stream. No other fishes were present in the reach of stream, but adult longfin dace, *Agosia chrysogaster,* were observed below the falls near Redrock Ranch, and young-of-year dace were noted in late May about 6 km downstream. In March 1979, a headwater tank about 7 km upstream from Gate Spring was seined. Small (< 150 mm)

Figure 2.—Photo (looking downstream) of the 150 m of stream in which five Gila topminnow were collected on May 18, 1979.

a

b

Figure 3.—Salt spring above and beside Redrock Creek in area of Gate Spring. See the tabulation for water chemistry. Arrow in (a) indicates position of spring pictured in (b).

Figure 4.—Example of extensive algal mats utilized by Gila topminnow for escape cover and as shade under summer conditions.

largemouth bass, *Micropterus salmoides,* were abundant, and a single mosquitofish was captured.

On August 23, 1979, we visited the Redrock Ranch and Gate Spring areas of Redrock Canyon. The stream had recently flooded (estimated flow, 500 m^3 per minute). The side-channel pool below Redrock Ranch had been severely eroded, but topminnows persisted there as well as in small, isolated schools in the mainstream where flow was 0.5 m^3 per minute. Topminnows were more abundant in the Gate Spring area than they were in May; however, the population level was lower than expected, apparently because of the flooding.

Literature Cited

Contantz, George Doran. 1979. Life-history patterns of a livebearing fish in contrasting environments. Oecologia 40(2):189-201.

Johnson, James E., and Gail Kobetich. 1968. A new locality for the Gila topminnow, *Poeciliopsis occidentalis* (Poeciliidae). Southwestern Naturalist 14(3):368.

McNatt, Randy, 1979. Discovery and loss of a new locality for the Gila topminnow, *Poeciliopsis occidentalis occidentalis* (Poeciliidae). Southwestern Naturalist 24(3): 555-556.

Minckley, W. L. 1969. Attempted re-establishment of the Gila topminnow within its former range. Copeia 1969: 193-194.

Minckley, W. L., John N. Rinne, and James E. Johnson. 1977. Status of the Gila topminnow and it co-occurrence with mosquitofish. USDA Forest Service Research Paper RM-198, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Rickel, Bryce. 1979. The status and management proposals for the threatened and endangered fishes of the Coronado National Forest. File 2630, Coronado National Forest, 16 p.

U.S. Department of the Interior. 1976. Endangered and threatened wildlife and plants (republication of list of species). Federal Register 41(208):47, 180-47, 198.

Rocky Mountains | Southwest | Great Plains

Research Note RM-383

March 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

An Artificial Bald Eagle Nest Structure

Teryl G. Grubb[1]

CLEMSON UNIVERSITY LIBRARY
JUN 17 1980
SCI., TECH & AGR. DIV.

Construction procedures are described for an artificial bald eagle nest support structure made of 4-inch aluminum pipe. The hinged, three-pole design permits complete assembly on the ground prior to raising and spreading the legs. The resulting tripod is inherently stable and offers natural support for a bald eagle nest and several perch branches more than 35 feet above the ground.

Keywords: *Haliaeetus leucocephalus*, nest structure, endangered species habitat, wildlife management

Several fallen bald eagle (*Haliaeetus leucocephalus*) nests have been successfully relocated in nearby, healthy trees (Dunstan and Borth 1970, Postupalsky 1978). One pair of eagles has been recorded nesting successfully on a 12-foot, three-legged platform designed for osprey (*Pandion haliaeetus*) in Michigan[2] (Postupalsky 1978). However, a permanent, totally artificial structure constructed specifically for bald eagle nesting was an unproven management technique until a prototype was developed in 1977.

Following the loss of an active nest and two viable eggs (Grubb and Rubink 1978), the structure was designed and constructed to benefit the resident pair of eagles which had a history of building nests in decadent, short-lived snags. Several years are normally required for bald eagles to successfully utilize artificial nest platforms (Postupalsky 1978), yet in 1978 the eagles accepted the tripod for occasional perching and roosting and in 1979 normal nest repair, egg laying, and incubation occurred. Unfortunately, the effort failed because the thin-shelled eggs broke before hatching; however, the artificial structure proved acceptable for bald eagle nesting.[3]

The tripod-teepee design was chosen because of its inherent stability and natural support for the nest and perch branches (fig. 1). Height, materials, use of shade, and other factors can be varied as circumstances require. The structure offers a new management dimension in supplementing marginal or deteriorated habitat and

Figure 1.—Bald eagle nesting tripod.

[1]*Research Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Tempe, in cooperation with Arizona State University; Station's central headquarters is at Fort Collins, in cooperation with Colorado State University*

[2]*Personal communication with Ralph E. Bailey, Michigan Department of Natural Resources.*

[3]*Teryl G. Grubb, Bald eagle activity at an artificial nest structure in Arizona. Manuscript in preparation.*

possibly in relocating nests to more suitable, less disturbed sites within an existing territory. Relocation is easily accomplished by removing the footing bolts, loosening the hinge bolts, and air lifting the collapsed tripod to a new location. This technique is being tested with the prototype structure during the 1980 breeding season; results will be reported when available.

Materials

Four-inch (inner diameter) aluminum pipe with 0.25-inch walls is recommended for the tripod because of its light weight and strength. Seven 20-foot sections of this diameter pipe are required to make the legs. One section is cut into three, equal, 80-inch pieces that ultimately serve as the upward extensions beyond the apex joint (fig. 2). Each leg is comprised of one short length and two standard, 20-foot lengths. Inner sleeves for the joints are made 40 inches long by cutting a 20-foot length of 3.5-inch-diameter (0.25-inch wall) aluminum pipe into six equal pieces. These sleeves, which fit perfectly into the 4-inch pipe, are inserted equidistantly into the two pipes being joined and bolted in place. Two 0.5-inch-diameter by 6-inch steel, machine bolts are used on each side of the joint, approximately 6 and 12 inches from center (fig. 2b). At the hinged apex and the footing attachments 0.75-inch steel all-thread cut in approximately 14-inch lengths provides greater strength at these stress points. Appropriately sized washers are placed on all bolts prior to tightening and locking with two nuts.

Standard, inexpensive, 8-foot railroad ties buried at least 5 feet in the ground make excellent footings because of their size and treatment against decay (fig. 2c). Redwood or cedar 2 by 4's of variable length can be predrilled and bolted to the upward extensions to form a simple framework for raising the nest, attaching branches, and/or constructing a shade screen (6-foot uprights and a 10-foot cross piece were used on the prototype, fig. 3). For attaching perch branches 0.25-inch all-thread in sufficient lengths is bent into the form of a large U-bolt. A 1- by 8-inch metal plate drilled with a series of holes makes a suitable base plate and allows for some width adjustment in the field. At least two such bolts are required per perch branch. U-bolts are an alternative method of attaching the 2 by 4 framework. One-inch mesh chicken wire is needed for bundling sticks to be tamped into the apex and also for holding the nest or nest materials when raising and wiring into place. Tie wire is satisfactory for the latter task and can also be used as an alternative means of holding perch branches in place. The aluminum pipe must be treated with zinc chromate primer before painting. The prototype was colored a desert tan and then later camouflaged with green and brown spray paint.

Table 1 provides a complete list of all materials needed. Special equipment required for construction beyond the obvious power tools, wrenches, etc., include a portable generator for drilling the footing bolt holes in the field, at least a 36-foot extension ladder for accessing the apex once the tripod is upright, and post hole diggers for setting the footings.

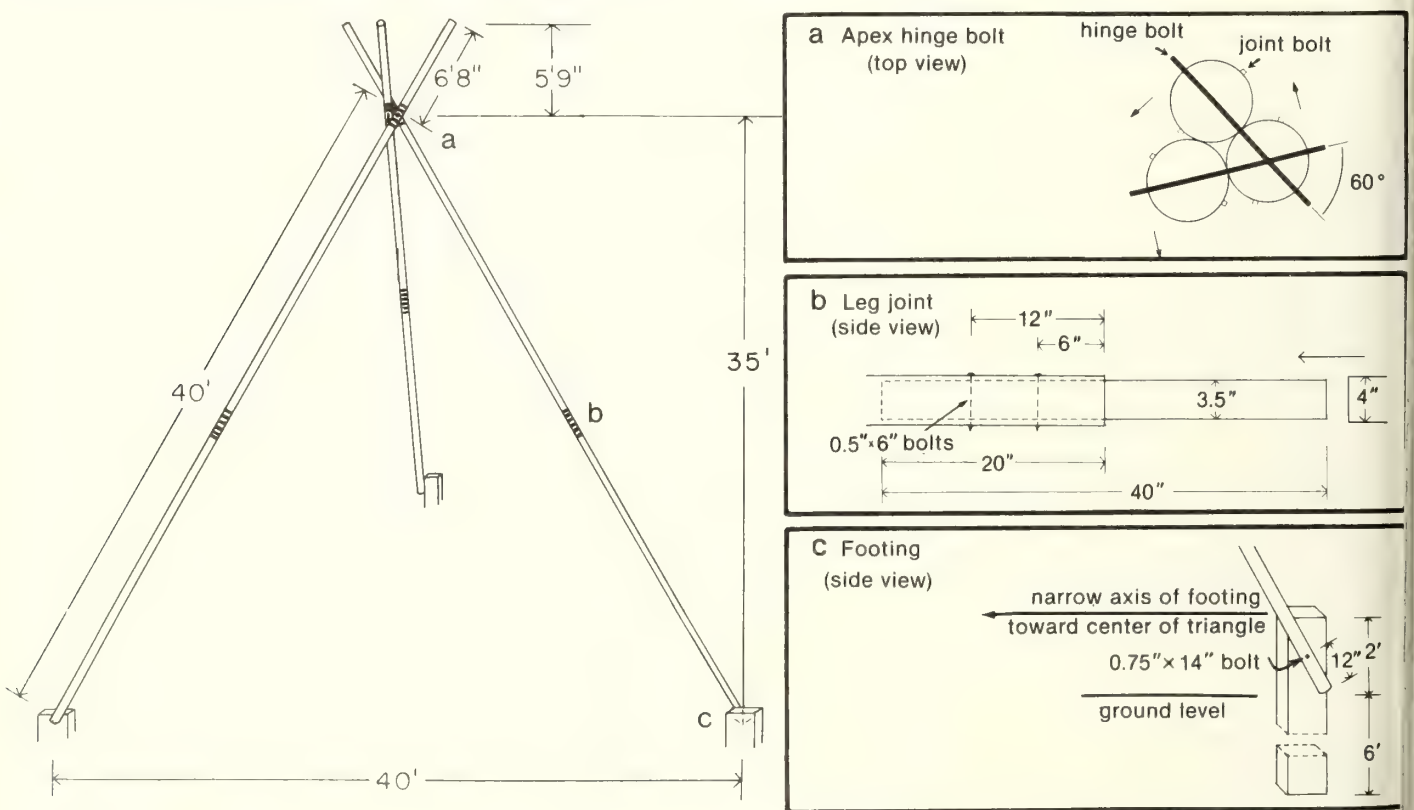


Figure 2.—Schematic of the nesting tripod showing dimensions and joints. (a)—Top view of tripod legs showing placement of hinge bolts. Arrows indicate direction of movement of upward extensions above pivot points when the legs are spread. Joint bolts are placed in the planes shown to avoid obstructing the legs' free movement. (b)—Schematic of the leg joints. (c)—Schematic of footing attachment.

Methods

In developing the prototype, a model of 0.5-inch dowling was constructed to determine the joint and hinge bolt angles necessary to allow the legs to swing free once upright. This design places the apex joints so that the three legs can be assembled and joined on the ground, raised simultaneously, and when spread into place, provide symmetrical nest support (fig. 2a). The model also proved useful for checking construction and positioning in the field. Assembly of a model before actual construction is strongly recommended for both planning and troubleshooting.

The aluminium pipe should be fitted and drilled in the shop. A drill press is best for this operation, but a 0.5-inch, hand-held power drill can be used. Bolt holes must be aligned so the protruding bolt heads will not interfere with the completed legs' movement when spread into place (fig. 2a). All pieces and holes should be labeled to facilitate proper fit and field alignment. Only the holes for the footing bolts are left for on-site drilling, to allow the weight of the structure to rest on the ground before the legs are secured to the footings. The pipe should be painted before leaving the shop, but extra spray paint in the field is usually required for touch up and camouflaging any wood framework attached after assembly.

Once on site the tripod legs are assembled and hinged loosely with two, 0.75-inch pieces of all-thread at 40 feet. The footings are buried at the points of a 40-foot equilateral triangle, oriented so the completed structure will have two upward extensions forming a plane facing south or

Figure 3.—Superstructure of the nesting tripod showing apex joint, 2 by 4 framework, perch branches, and nest materials.

Table 1.—Material list for constructing basic bald eagle nesting tripod

Item	Quantity
Aluminum pipe, 0.25-inch wall thickness	
4.0-inch inner diameter by 20 feet	7
3.5-inch inner diameter by 20 feet	1
Railroad ties, 6 inches by 8 inches by 8 feet	3
Steel bolts, 0.5-inch diameter by 6 inches	24
compatible nuts	48
compatible flat washers	48
Steel all-thread, 0.75-inch diameter by 14 inches	5
compatible nuts	20
compatible flat washers	10
Paint	
zinc-chromate aluminum primer	1 gallon
base paint (brown, green, or gray)	1 gallon
green spray paint	2 cans
brown spray paint	2 cans
Chicken wire, 1-inch mesh, 6-foot width	20 feet
Tie wire, 14 gauge	1 roll
All-thread, 0.25-inch diameter by 18 inches	6
compatible nuts	12
compatible locking washers	12
Flat metal plates, 1 inch by 8 inches	6
Optional 2 by 4 framework, cedar or redwood	
10-foot length	1
6-foot length	2
bolts, 0.5-inch diameter by 7 inches	4
bolts, 0.5-inch diameter by 4 inches	2
compatible nuts	12
compatible flat washers	12

southwest. This allows construction of a sun shade between those arms if necessary (fig. 4). In areas of high winds, a similar procedure could be used to locate an effective wind screen. A helicopter with a payload of at least 700 pounds (the assembled tripod weighs about 675 pounds) is recommended for raising the tripod and lifting the legs sufficiently off the ground for them to be spread to the footings. An alternative method of raising the tripod by hand (or vehicle) with lines, winches, and a boom is also considered feasible. Before drilling and bolting to the footings, the legs once upright can easily be positioned by two men. To avoid binding and hinge damage, it is important to spread the tripod legs as shown in figure 2a (i.e., above the apex, the upward extensions swing counter-clockwise, while the longer legs below open clockwise). Color coding the legs and their respective footings with spray paint is recommended to facilitate proper leg placement.

The apex bolts must be tightened after the legs are secured to the footings. A helicopter can be used to place a bundle of sticks wrapped in chicken wire into the apex to provide a platform for the nest, which can be raised in a similar fashion. These tasks can also be accomplished by bolting two 2 by 4's and a cross arm to the upward extensions and using a pulley and ropes to raise the materials. Care should be exercised to place the cross arm high enough above the apex to permit the nest to swing in freely over the top of the initial stick bundle. This framework

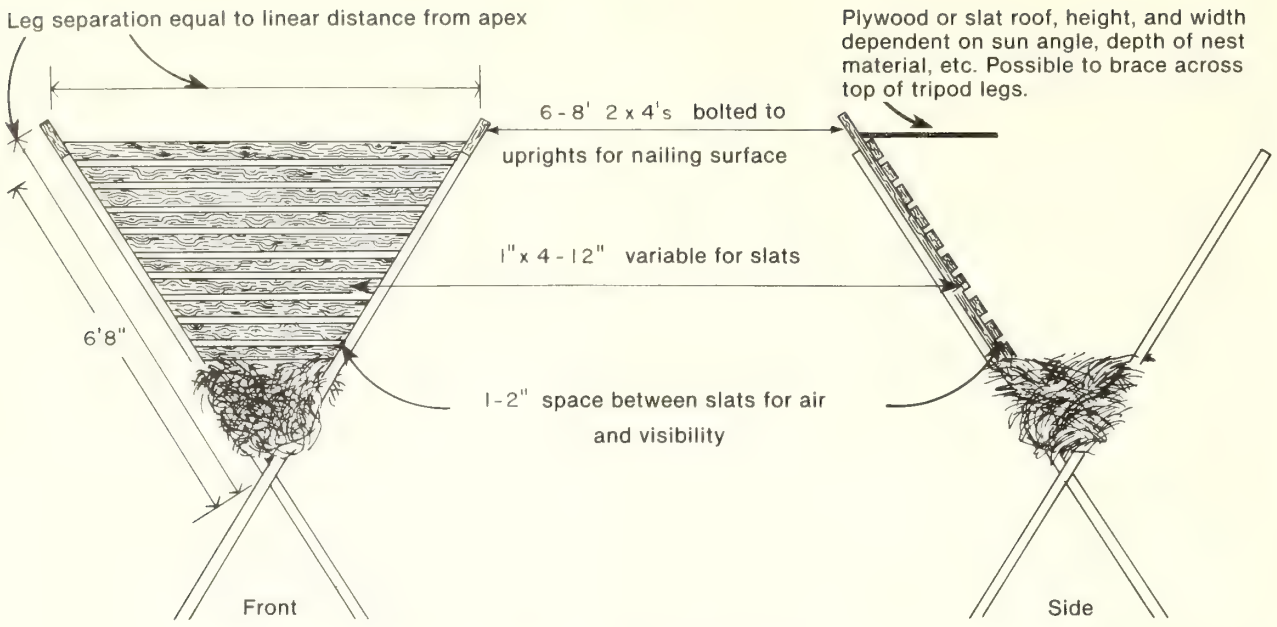

Leg separation equal to linear distance from apex
Plywood or slat roof, height, and width dependent on sun angle, depth of nest material, etc. Possible to brace across top of tripod legs.
6 - 8' 2 x 4's bolted to uprights for nailing surface
1" x 4 - 12" variable for slats
6'8"
1-2" space between slats for air and visibility
Front
Side

Figure 4.—An optional, untested, sun-wind screen for the bald eagle nesting tripod.

can be left in place as a perch support and a working surface for a sun or wind screen. A third method involves securing chicken wire in the apex and adding sticks until a suitable nest is achieved. The chicken wire support for the sticks and nest permits wiring them securely to the tripod legs. The last step is to bolt (or wire) a large perch branch to each of the upward extensions. On the prototype, 10- to 12-foot, dead branches already dried and thus relatively light proved satisfactory for this purpose (fig. 3). Four-inch plywood discs can be glued to the open ended pipes to prevent any accumulation of debris that might hinder future bolt adjustments.

Discussion

Wood originally appeared to be a more economical and natural material for the tripod legs, but the 1,100-pound weight of a single, 50-foot telephone pole was prohibitive. A sun or wind screen was not included on the prototype structure because the old nest tree it replaced offered no such protection, other than the branches that were used on the tripod. A screen can easily be added at the time of construction or any time thereafter (fig. 4). One consideration is that the branches alone appear more natural. Another modification that did improve the "naturalness" of the prototype structure was camouflaging the legs with dark brown and green spray paint. The original tan color blended well with the desert landscape but did not hide the straight line of the legs. The tripod was much less conspicuous when camouflaged. At the apex, construction might be facilitated by the addition of a disc platform or 2 by 4's bolted just above the 40-foot joint. These would provide a foothold for a worker and support for both the first bundle of sticks and the nest.

The cost of the tripod materials, including about an hour of helicopter time, is estimated at $1,200. The actual cost of the prototype was less than $900, but helicopter time was negligible; only 10 minutes were required to stand the tripod upright. Also the aluminum, which comprises the major portion of the cost, has risen to about $135 per 20-foot section of 4-inch pipe as priced in 1979. Approximately 150 man-hours were required for site preparation, shop work prior to field assembly, and actual construction of the prototype structure. Site preparation requirements will vary with location, but the time necessary for tripod construction should be less than 80 man-hours on future projects. It should be noted, however, that depending on how the structure is raised, 6 to 12 people are needed briefly to handle guy lines, spread the legs, etc.

Literature Cited

Dunstan, Thomas C., and Melvin Borth. 1970. Successful reconstruction of active bald eagle nest. Wilson Bulletin 82(3):326-327.

Grubb, Teryl G., and Duane M. Rubink. 1978. First bald eagle eggs collected for analysis in Arizona. USDA Forest Service Research Note RM-352, 2 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Postupalsky, Sergej. 1978. Artificial nesting platforms for ospreys and bald eagles. p. 34-45.*In* Endangered birds—Management techniques for preserving threatened species. S. A. Temple, editor. University of Wisconsin Press, Madison.

Acknowledgements

This project has been a cooperative effort between the Rocky Mountain Forest and Range Experiment Station, Tonto National Forest, and the U.S. Fish and Wildlife Service. The Fish and Wildlife Service Office of Endangered Species in Albuquerque provided the funds for materials, while Youth Conservation Corps personnel from the Tonto National Forest helped prepare the construction site.

Errata for

USDA Forest Service Research Note RM-384
Raising Bur Oak in Containers in Greenhouses

In table 1, page 5, the last line should read:

pH	6.5	6.5

Rocky Mountains | Southwest | Great Plains

Research Note RM-384

May 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Raising Bur Oak in Containers in Greenhouses

Richard W. Tinus[1]

SEP 11 1980

Under optimum conditions, two crops of bur oak (*Quercus macrocarpa*) can be grown per year. Because bur oak requires high temperature for rapid growth, the most economical approach is to grow both crops during the spring and summer by starting early and hardening the first crop in a shadehouse and the second crop in the greenhouse. Procedures are given for seed handling, regulating climate, watering and fertilizing, and hardening.

Keywords: *Quercus macrocarpa*, seed crops, greenhouses, containerized tree seedlings.

There are problems growing oaks in an outdoor bare-root nursery, because they are strongly taprooted and tend to be slow growing. If they are not undercut several times, most of the fine roots will be lost when they are lifted, and field performance will be poor. If they are undercut, it will be difficult to achieve adequate height growth, unless the growing time is extended. Both problems can be solved by growing oaks in containers in greenhouses.

A growing regime has been developed to grow 20- to 25-cm-tall stock, with 5- to 8-mm caliper, in large containers, for spring planting in the northern Great Plains. Because oak grows fast under optimum conditions, two crops can be grown per year. However, bur oak requires high temperature for rapid growth (Tinus 1974). Therefore, the most economical approach is to grow both crops during the spring and summer. This is possible by starting early and hardening the first crop in a shadehouse and the second crop in the greenhouse.

Because of the large seed size, oaks should be grown in containers not smaller than 300 ml. Suitable containers include the 20-cubic-inch (320-ml) BC/CFS styroblock, 30-cubic-inch (410-ml) Colorado State styroblock, and Spencer-Lemaire 30- and 45-cubic-inch (700-ml) Root-rainers.[2]

[1]*Plant Physiologist, Rocky Mountain Forest and Range Experiment Station, at the Station's research work unit at Bottineau, in cooperation with North Dakota State University. Station's headquarters is at Fort Collins, in cooperation with Colorado State University.*

[2]*Mention of trade names is for the convenience of the reader and does not imply endorsement by the U.S. Department of Agriculture to the exclusion of equally suitable products.*

The growing medium used is 1:1 horticultural grade no. 1 or no. 2 sphagnum peat and vermiculite with a 3- to 5-mm particle size. It is well drained, yet has good moisture-holding capacity, and the pH can be maintained between 6 and 7 with an appropriate nutrient solution. About 3% forest duff is incorporated into the growing medium to provide mycorrhizal fungi. How essential this is for oak is not known, but inoculation of other genera ranges from useful to vital. Duff inoculation risks introducing harmful organisms, but in a few years there may be pure cultures of mycorrhizal fungi of proven value on the market.

Seed Handling

With most species, multiple seeding can compensate for low or slow germination. However, this is usually impractical with large seeded species such as walnut, pecan, or oak, because only one seed will fit in a cavity. Acorns have a short storage life compared to many species. They cannot be allowed to dry out, and they cannot be frozen (fig. 1) (Tinus 1978). Bur oak from North Dakota is unusual in that it is one of the few white oaks that require stratification. The acorns are frequently infested with weevils (*Curculio* or *Conotrachelus* spp.), although they appear to have little effect on viability if the following collection and storage guidelines are followed (Tinus 1977):

1. Collect the seed from the ground or shake the tree, but do not pick green seeds. This insures adequate ripeness and is also the easiest way to collect the seed.

2. Immediately float test the seed in water. Anything that sinks will germinate 80-90%, and anything that floats will germinate 0-30%. This eliminates seeds which have been damaged by drying or weevils, stops the drying, and ensures full hydration for stratification.
3. Place the wet acorns in a plastic bag. Store them in a cooler just above freezing, but do not freeze them. This will provide the right moisture and temperature for storage and stratification.
4. When it is time to plant, bring the acorns into a warm room for a few days in advance and allow the radicles to emerge. Plant one germinant per cavity with the top of the acorn about 1 cm below the surface. This will insure a virtually 100% stand. Return the ones that did not germinate to the cooler, and save them for the second crop.

Seed normally is collected in North Dakota in September. With 60 days' stratification, sowing could be scheduled anytime after December 1, usually March 15 (fig. 2). Because acorns germinate very quickly after 135 days in stratification, no more should be brought out of the cooler than can be planted in 2 days. After the first crop is planted, the remainder of the acorns should be stored as cold as possible without freezing, to prevent germination in storage.

The first crop reaches 20- to 25-cm height after three flushes by the middle of June. At this time it can be transferred to a shadehouse to complete its caliper and dry weight growth, and the second crop can be started in the greenhouse. The second crop might reach full height in time to be hardened in the shadehouse. Hardening in the shadehouse is desirable, because it is cheaper than hardening in a greenhouse. It would be possible to begin germination of the first crop several weeks earlier, but this is pushing greenhouse operation into the expensive part of the year. Crop 1 could be removed from the greenhouse before height growth is completed because it would have most of the summer to finish its growth. This is risky because the oak will stop height growth unless the weather is hot and humid. Even in midsummer, that is often not the case in North Dakota. Therefore, the second crop is hardened and overwintered in the greenhouse.

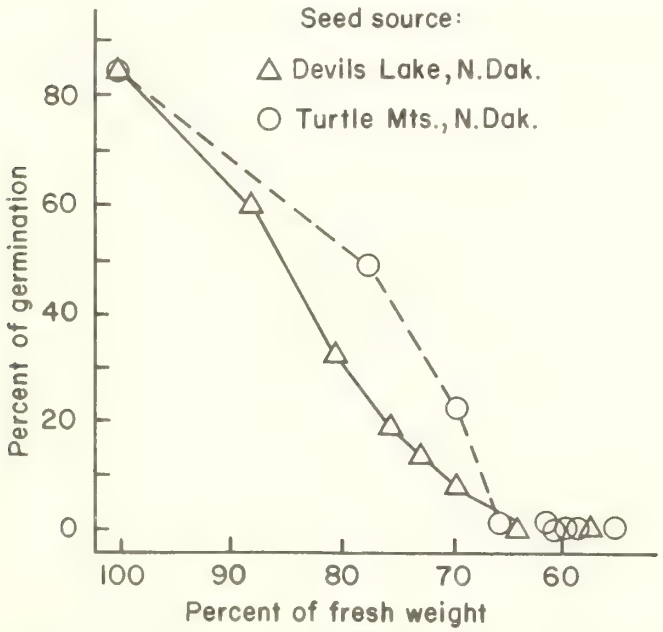


Figure 1.—Germination of *Quercus macrocarpa* acorns as a function of weight loss due to drying.

Germination

Initial germination will occur in bags or trays at room temperature. After planting, the greenhouse heating should be set for about 21° C (70° F) day and night with the cooling set to hold temperatures under 27° C (81° F) until the seedlings are well established and the first set of leaves have fully expanded.

Relative humidity can be set at 70% with an allowable range of 50-90%. Unlike small seeded species, it is not necessary to give frequent light waterings to oak because it is a large seed, and the bulk of it is 10-15 mm below the surface. Leaves should not have standing droplets of water on them for more than a few hours a day because that invites fungal infection.

Photosynthesis of oak saturates at quite low sunlight intensities, and yet, bur oak can tolerate high light intensity. Shading is not necessary unless day temperatures cannot be held in the optimum range. That range is high, however, and as often as not, intense sunlight may help raise the temperature.

It is not known whether supplemental light is necessary to maintain height growth, but it is known that supplemental light is ineffective unless temperature is kept high. Since intermittent incandescent light is not expensive, it would be advisable to have it on after the first leaves have expanded.

Watering should be as needed to keep the rootball moist. The surface should dry between waterings, and no fertilizer applied or the CO_2 generator turned on until the majority of seedlings have their first leaves fully expanded.

Multiple Flushing Stage

After the seedlings are well established, the day temperature should be raised to about 90° F (32° C). An efficient way to do this would be to leave the furnace setting at about 75° F (24° C) and set the first cooling stage at 32° C with full cooling on by 98° F (37° C). This may seem incredibly hot to some nurserymen, but it is the environment required to maintain multiple flushing of bur oak (Tinus and McDonald 1979).

Relative humidity should be kept fairly high, because at high temperatures the transpiration stress is greater for a given relative humidity than at lower temperatures. (Note that the combination of high temperature and humidity will make working in the greenhouse very uncomfortable, and jobs in the greenhouse should be scheduled for the early morning. Workers not accustomed to the heat and humidity should eat enough salt, drink enough water, and take occasional breaks (Johansson and Mattson 1975).)

After the supplemental light and CO_2 are turned on and fertilization with each watering has begun, no further changes are needed until the crop has reached full height and is moved to the shadehouse.

Season	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage	Germination	Juvenile growth	Multiple flushing	Crop #1 Bud set; Germinate Crop #2	Juvenile growth	Multiple flushing	Natural hardening Bud set, leaf fall		Cold hardening meet chilling requirements	Maintain dormancy			
Day temp (°F) Optimum	70	90		Crop #2 70	Crop #2 90			70	34	34			
Day temp (°F) Permissible	68-80	80-95		68-80	80-95			60-80	32-40	28-50	(Rootball should not remain continuously frozen)		
Night temp (°F) Optimum	70	72		70	72			55	34	34			
Night temp (°F) Permissible	68-80	66-80		68-80	66-80			45-70	32-40	28-40			
Rel. Hum. (%) Optimum	70	70		70	70			Same	Same	Same			
Rel. Hum. (%) Permissible	50-90	50-90		50-90	50-90			Same	Same	Same			
Daylight	50-90% of full Sunlight			Same	Same			Same	Same				
Supplemental light	None	8 watts/ft² incandescent light on 1 min. out of every 15 min. (or 6% of the time, provided no dark period is longer than 30 min.) throughout the night.						None					
Water	As needed. Surface should dry between waterings. Maintain rootball moisture stress at 0.5-3 bars. Fertilize (except during germination) and water in excess at every watering.							Same					
Fertilizer	None	Complete, high N, pH 5.8-6.8, conductivity 1,800 ±300 μmhos.		Crop #1: As before using low N, high PK. Crop #2: As before using high N.				Both crops receive low N, high PK.					
CO_2 level	Normal atmos.	1,000-1,200 ppm whenever vents are closed during daylight hours.		Normal atmos.	Crop #2: 1,000-1,200 ppm whenever vents are closed during daylight hours.			Normal atmosphere					
Operations	Germinate seed; Plant seed			Move Crop #1 to shadehouse			Collect seed	Mulch Crop #1				Move Crop #2 to shadehouse	

Figure 2.—Growing schedules for two crops per year of bur oak in 30-cubic-inch containers at Bismarck, N. Dak., for spring outplanting (Tinus and McDonald 1979).

The broad horizontal leaves of oak shed water, which makes uniform watering difficult and increases the edge effect. At optimum temperatures, oaks grow rapidly (fig. 3), and the available moisture in the pot mix does not last as long. Therefore, they must be watered more often as they grow. It is easy to tell when they are moisture stressed, because the leaves wilt visibly. However, foliage is quickly damaged, and it is important to avoid wilting during rapid height growth.

Oaks do best when the nutrient solution is kept at pH 6-7. The high N formulation listed in table 1 has been found suitable, but is probably not optimum. After watering with nutrient solution, the foliage is usually rinsed to remove salts and avoid leaf injury when the droplets dry.

Oaks require protection against insects. Every hardwood nursery operator should become familiar with the appearance of aphids, whiteflies, spidermites, and plant bugs, and the damage they cause. The best control is to clean out the house completely between crops, and then fumigate. Second, be vigilant. Insect populations start small and grow rapidly. Spot spray when harmful insects are first noticed. If populations are building, begin regular weekly spraying and change insecticides to catch a wider spectrum of insects and retard the development of resistance. Alternating between nicotine sulfate, Kelthane,[2] and malathion is highly effective.

If the growing medium is well drained and the seedlings are mycorrhizal, there is rarely any problem with root rots. Leaf spot diseases such as *Anthracnose* are common, however, and should be controlled with appropriate fungicides. Some of these organisms can also enter the stem and cause dieback.

Occasionally, rodents find the seed and do a lot of damage in a matter of days. If a problem is anticipated, bait the floor and entryways with rolled oats treated with zinc phosphide.

Hardening

When the first crop is moved to the shadehouse, the nursery operator immediately loses control of temperature and humidity, and there will be no supplemental CO_2 or light at night. In mid-June, there should be no problem moving very succulent material out of the greenhouse, but the transition to cooler nights, probably cooler days, and much lower humidity, should trigger budset. If budset does not occur within 2 weeks, withhold water until the seedlings are at the permanent wilting point, then rewater.

Once in the shadehouse, water the seedlings as needed but with the low-N, high-PK formulation (table 1). This should be continued throughout the summer and fall as long as the day temperatures are above freezing and the rootballs are not frozen. About the time the rootballs begin freezing and after the leaves have fallen, bait the containers with rolled oats containing zinc phosphide and mulch around the sides and over the tops of the seedlings with sawdust, coarse peat, or other suitable material. The shadehouse must be rabbitproof. No other care is required until the stock is ready to be shipped in the spring. At this time, the mulch is removed, and the stock is watered thoroughly with high N nutrient solution just prior to shipment.

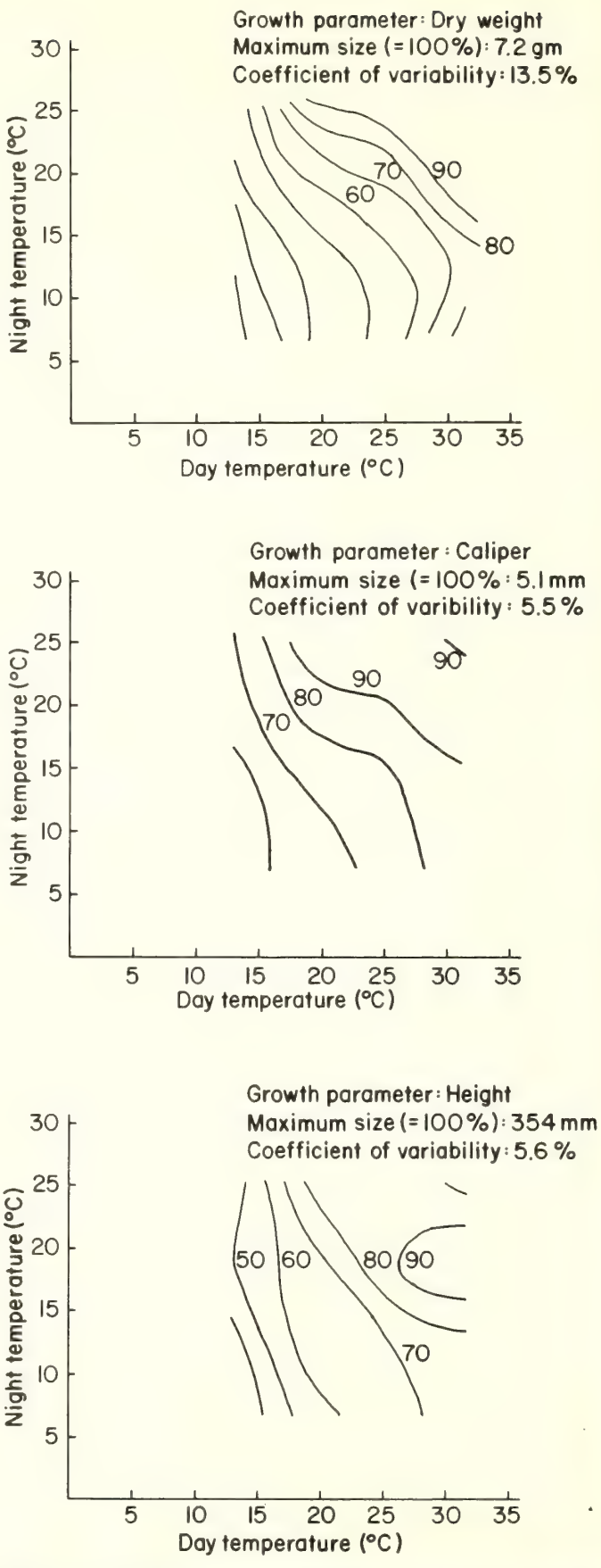


Figure 3.—Growth of bur oak seedlings (source: Devils Lake, N. Dak.) as a function of day and night temperatures (Tinus and McDonald 1979).

Table 1.—Nutrient solutions suitable for bur oak

Mineral nutrient	High N—use for rapid growth	Low N, high PK—use for hardening
	p/m	*p/m*
N as NO_3	156	12
N as NH_4	67	8
P	27	60
K	155	155
Ca	60	60
Mg	40	40
S	63	63
Fe	4	4
Cl	4	4
Mn	0.5	0.5
B	0.5	0.5
Zn	0.05	0.05
Cu	0.02	0.02
Mo	0.01	0.01
pH	5.5	5.5

The second crop is handled exactly the same way through the germination and multiple flushing stages. On October 1, when hardening in the greenhouse begins, temperatures are reduced to levels that will stop flushing, set buds, and continue caliper growth, particularly in the taproot. It is not necessary to drought stress the seedlings to cause this.

Supplemental light at night is shut off to put the crop on a short photoperiod. The high CO_2 must also be turned off at the beginning of the hardening of oaks, because CO_2 retards leaf abscission and may promote bud break and renewed height growth.

Watering is continued as needed but with the low-N, high-PK formulation.

Normal abscission of the leaves is an important part of the hardening process. Accelerating leaf abscission has not been very successful. Chemicals that effectively remove the leaves cause dieback the following spring (Fuchigami 1977, Fuchigami et al. 1977).

Cold nights will cause the development of fall colors and begin the development of an abscission layer, but the leaves generally will not fall off until well into the second stage of hardening when the temperature is brought very close to freezing. No other changes in conditions are needed to go from the first to the second stage of hardening. The conditions are maintained throughout the winter. After 2 weeks at low temperatures, frosts will not hurt the seedlings, but the rootballs should not be allowed to remain frozen for weeks at a time.

The second crop is removed from the greenhouse before March 7 so that the next year's first crop can be planted. This can be done anytime after December 15. They should be moved to the shadehouse in mild weather, if possible, the seedlings placed flat on the ground and mulched immediately. Both crops will be ready to ship for spring planting.

The growing regime described has been thoroughly tested for raising bur oak in North Dakota. Limited experience indicates that this regime is suitable, if not optimum, for northern red and black oak as well.

References

Fuchigami, L. H. 1977. Ethephon-induced defoliation and delay of spring in growth in *Cornus stolonifera* Michx. Journal of the American Society of Horticultural Science 102(4):452-454.

Fuchigami, L. H., M. Motze, and C. J. Weiser. 1977. The relationship of vegetative maturity to rest development and spring bud-break. Journal of the American Society of Horticultural Science 102(4):450-452.

Johansson, I., and A. Mattson. 1975. Arbetsmiljon i vaxhus, arbetstynged och klimat. Research Note 65, 17 p. Royal College of Forestry, Department of Reforestation, Stockholm, Sweden.

Tinus, Richard W. 1974. Large trees for the Rockies and Plains. p. 112-118. *In* Proceedings of the North American containerized forest tree seedling symposium. [Denver, Colo., August 1974] Great Plains Agricultural Council Publication 68, 458 p.

Tinus, R. W. 1977. Production of container grown hardwoods. p. 126-136. *In* Proceedings of the Intermountain Nurserymen's Association annual meeting. [Manhattan, Kans., August 1977] Wm. Loucks, editor. State and Extension Forestry, Kansas State University, Manhattan.

Tinus, R. W. 1978. Production of container grown hardwoods. Tree Planters' Notes 29(4):3-9.

Tinus, Richard W., and Stephen E. McDonald. 1979. How to grow tree seedlings in containers in greenhouses. USDA Forest Service General Technical Report RM-60, 256 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some states have restrictions on the use of certain pesticides. Check your state and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or state extension specialist to be sure the intended use is still registered.

Rocky Mountains | Southwest | Great Plains

Research Note RM-385

June 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Risk Rating Guide for Mountain Pine Beetle in Black Hills Ponderosa Pine

Robert E. Stevens, William F. McCambridge, and Carleton B. Edminster[1]

CLEMSON UNIVERSITY LIBRARY
SEP 1980
SCI., TECH & AGR. DIV.

Average tree diameter, stand density, and stand structure are key elements used in the rating. Single-storied stands are most susceptible to heavy mountain pine beetle damage. Risk increases with d.b.h., reaching a maximum when trees are 12 inches d.b.h. and larger. During buildup of an outbreak, denser stands within a given mean diameter are more susceptible to invasion.

Keywords: Insect control, Scolytidae, bark beetles, *Dendroctonus ponderosae, Pinus ponderosa.*

Ponderosa pine stands in the Black Hills of South Dakota and Wyoming vary in their susceptibility to mountain pine beetle (MPB) outbreaks. This rating guide is designed to help land managers recognize stand conditions that are associated with low, medium, and high susceptibility (or risk) to MPB-caused losses. Similar guides have been prepared for other beetle-host associations (Amman et al. 1977, Lorio 1978, Safranyik et al. 1974, Schmid and Frye 1976). Using these guides, the land manager can compare stands and assign priority for thinning or other kinds of actions to those having the greatest risk of beetle-caused damage.

This rating guide is based on observations that provide insight into the kinds of stand conditions associated with MPB outbreaks (Sartwell and Stevens 1975) and the authors' experience with ponderosa pine and MPB in the Black Hills and elsewhere.

Three stand characteristics affect susceptibility to beetle attack: (1) stand structure, (2) average d.b.h. of the ponderosa pine component, and (3) stand density as expressed by average basal area per acre. Diameter growth rates, discussed by Sartwell and Stevens (1975), are closely correlated with stand density and are not considered separately.

[1]*Entomologists and Mensurationist, respectively, Rocky Mountain Forest and Range Experiment Station. Headquarters at Fort Collins in cooperation with Colorado State University.*

Also, species composition is not included because relatively few acres of ponderosa pine are found in mixture with aspen, birch, or spruce, the other important tree species in the Black Hills.

This guide is designed to be applied to forest stands only; it will not work if applied to other kinds of units. A stand must be consistent in species composition, site quality, structure, tree density, and past treatment. Note that size (area) is not a stand characteristic.

Stand Structure

The single-storied ponderosa pine stand is most susceptible to heavy MPB damage. It is most likely to become damaged first and also to suffer heavier losses (i.e., larger groups of killed trees and more of them). An arbitrary risk rating of 3 (table 1) has been assigned to such stands. Next in susceptibility is the two-storied stand, where attention is focused on the characteristics of the overstory trees. As tree size and density increase, these stands increase in susceptibility to approximate that of the even-aged stand. An overall risk of 2 is assigned to two-storied stands.

The multistoried stand is too small a component of the Black Hills forest to include in risk rating. As more acreage comes under management, such stands will presumably become a significant portion of the forest and can then be rated as experience with them develops.

Table 1. --MPB risk classes for Black Hills ponderosa pine

	Risk classes		
	1 = low	2 = moderate	3 = high
Stand structure	—	2-storied	single-storied
Average stand d.b.h. (inches)	<6	6-10	>10
Stand density (square feet per acre)	<80	80-150	>150

Mean Stand Diameter

As d.b.h. increases, risk of beetle outbreak also tends to increase, reaching a maximum when trees are around 12 inches d.b.h. and larger. Consequently, as mean stand diameter increases (i.e., the d.b.h. of the tree of average basal area), the risk of that stand being destroyed also increases. The risk is high (3), moderate (2), or low (1) when mean stand diameter, in trees at least 5 inches d.b.h., is more than 10 inches, 6 to 10 inches, or less than 6 inches, respectively. It is difficult to predict how much more susceptible a stand having a mean d.b.h. of 8 inches is than one having a mean d.b.h. of 12 inches or more. However, heavily damaged stands in the Black Hills are usually in the 10- to 12-inch d.b.h. range.

Stand Density as Basal Area Per Acre

During the years a mountain pine beetle outbreak is building to its maximum destructive capability, the more dense the ponderosa pine stand is within a given mean diameter, the more susceptible it will be to severe losses. At maximum outbreak levels, this pattern is less evident because beetles must attack trees in a variety of conditions.

Stand density is arbitrarily ranked high (3), moderate (2), or low (1) when the basal area of ponderosa pine stems—in trees greater than 5 inches d.b.h.—is greater than 150 square feet per acre, 80 to 150 square feet per acre, or less than 80 square feet per acre.

Using the Risk Plan

The user evaluates the characteristics of a stand and assigns to it the appropriate risk values shown in table 1.

First, determine whether the stand is single- or two-storied. Second, estimate stand density in trees 5 inches and larger and average stand d.b.h. Select risk values from table 1 and calculate risk by multiplying these together. Risk is then as follows:

Stand risk value	Risk rating
2-6	Low
8-12	Moderate
18-27	High

For example, consider a single-storied stand (risk 3) with a basal area of 180 square feet per acre (risk 3) and a mean d.b.h. of 11.2 inches (risk 3). The relative risk of such a stand is 27 (3 x 3 x 3). Such a stand is the most susceptible to MPB attack. If the average d.b.h. of the stand is 8 inches, the risk is 18 (3 x 3 x 2)—still high, but closer to moderate. The least susceptible stand, a two-storied thin stand of small trees, would rate 2 x 1 x 1, or at the bottom of the low risk category.

Other Factors

The maximum size area to be given a single rating will probably be the main difficulty users experience with this plan. Some judgment in interpreting the guidelines in particular areas is necessary.

The key, as Schmid and Frye (1976) discuss in their risk-rating plan for spruce beetle, is to properly distinguish a stand. If the forest area in question does not fit the definition of a stand, particularly with respect to the three characteristics in this guide, ratings will probably be inaccurate.

Consider, for example, a 100-acre unit of ponderosa pine forest. Stand density over the entire unit may average 60 square feet per acre. If we used this average, it would work into our rating plan as "low risk." But if the overall area were made up of several 5- to 10-acre stands with densities approximately 200 square feet per acre and only widely scattered trees over the remainder, "low risk" would not properly categorize the entire area. The thickets are individual stands and would properly be classed "high risk."

Literature Cited

Amman, Gene D., Mark D. McGregor, Donn B. Cahill, and William H. Klein. 1977. Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA Forest Service General Technical Report INT-36, 19 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Lorio, Peter L., Jr. 1978. Developing stand risk classes for the southern pine beetle. USDA Forest Service Research Paper SO-144, 9 p. Southern Forest Experiment Station, New Orleans, La.

Safranyik, L., D. M. Shrimpton, and H. S. Whitney. 1974. Management of lodgepole pine to reduce losses from the mountain pine beetle. Environment Canada Forestry Service, Forestry Technical Report 1, 24 p.

Sartwell, Charles, and Robert E. Stevens. 1975. Mountain pine beetle in ponderosa pine—Prospects for silvicultural control in second-growth stands. Journal of Forestry 73(3):136-140.

Schmid, J. M., and R. H. Frye. 1976. Stand ratings for spruce beetles. USDA Forest Service Research Note RM-309, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Agriculture—CSU, Fort Collins

Rocky Mountains | Southwest | Great Plains

Research Note RM-386

June 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

79 AM - 58

Control of New Mexican Locust and the Effect on Planted Ponderosa Pine in Central Arizona

Gerald J. Gottfried[1]

CLEMSON UNIVERSITY SEP 11 1980 SCI., TECH & AGR. DIV.

Several herbicide applications were necessary to control New Mexican locust; however, first-year ponderosa pine seedling survival appeared to benefit from partial shade from locust sprouts which were not sprayed. In a separate study, soil moisture conditions in the top 24 inches (60 cm) were better in 5-year-old locust sites than in grass or 20-year-old locust sites. Managers may be able to manipulate the seral locust cover to speed pine regeneration.

Keywords: *Robinia neomexicana, Pinus ponderosa,* brush control, seedling survival

Many potentially good quality ponderosa pine[2] sites in Arizona and New Mexico are stocked with dense thickets of New Mexican locust (fig. 1), which impede conifer growth. New Mexican locust is a spiny shrub or small tree that grows in pure stands or as an understory species in ponderosa pine and mixed conifer stands between 4,000 and 8,500 feet (1,200 to 2,550 m) (Little 1950) in the Southwest (fig. 2). It is frequently found in association with Gambel oak. Locust sprouts readily and grows rapidly, especially after disturbances. It often competes with ponderosa pine and other conifer seedlings and saplings for moisture and light. Conifers eventually succeed locust, but it may take decades. Conifer planting could speed up the succession, but often this is not successful.

Locust control would reduce competition between the two species. Herbicides, possibly used in combination with prescribed burning or mechanical methods, may help

Figure 1.—New Mexican locust often forms dense, impenetrable stands after disturbances on ponderosa pine and lower mixed conifer sites (South Fork of Workman Creek). The area around this photo-point contains an average of 5,833 stems of locust and Gambel oak per acre. (14,408 stems per hectare).

[1]*Research Forester, Rocky Mountain Forest and Range Experiment Station. Headquarters is at Fort Collins, in cooperation with Colorado State University. Research was conducted at the Station' Research Work Unit at Tempe, in cooperation with Arizona State University.*

[2]*Common and scientific names of plants mentioned are listed in appendix.*

establish ponderosa pine plantations. Mechanical site preparation without herbicides is unsuccessful unless roots are ripped from the ground; otherwise, sprouts quickly reoccupy the site. The use of fire has not been tested. Since New Mexican locust sites often contain satisfactory residual pine, herbicides must be selective.

Some researchers (Ryker and Potter 1970, Youngberg 1966, Coffman 1975) indicate that brush may be beneficial to early conifer survival, especially where extreme environmental pressures exist. Youngberg (1966) concluded that moisture conditions were more favorable under brush canopies than in openings during initial seedling development. Many brush species also increase soil fertility by nitrogen-fixation and litter production. However, brush competition usually becomes a problem later.

Coffman (1975) found that several brush species, including locust, increased first-year survival of planted Douglas-fir in New Mexico. Little is known about ponderosa pine establishment in New Mexican locust sites. Although ponderosa pine is intolerant to shade, it is possible that locust may aid pine establishment, although it probably would have to be eliminated later.

Study Area

The exploratory studies reported here were conducted on the South Fork of Workman Creek within the Sierra Ancha Experimental Forest, about 30 miles (48 km) north of Globe, Ariz. Annual precipitation, measured at South Fork, has averaged (with standard error) 32.20 ± 9.61 inches (805 ± 240 mm) from 1956 to 1977, with two-thirds falling from October through May. Annual temperatures average 48° F (8.9° C), varying from 31° F (−0.6° C) in January to 65° F (18.3° C) during July and August.

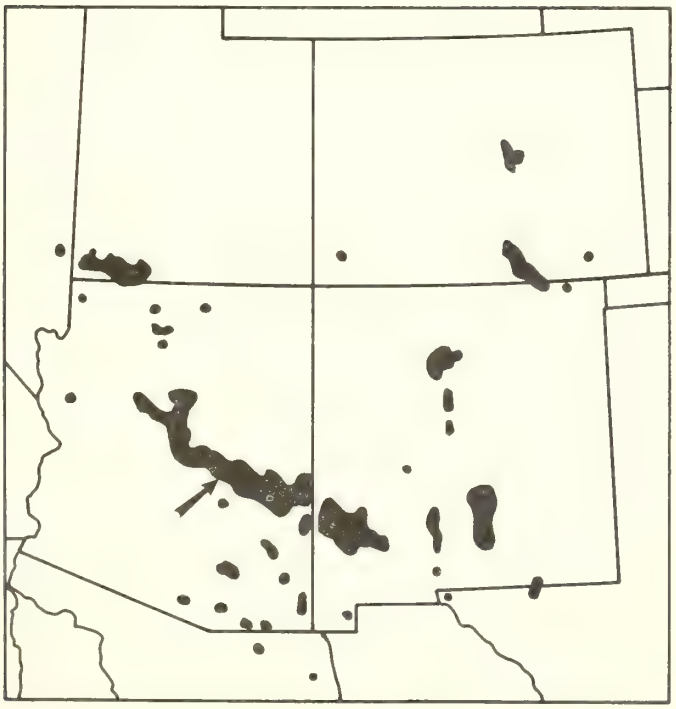


Figure 2.--The range of New Mexican locust (Little 1976). The arrow indicates the approximate location of Workman Creek.

Dripping Springs quartzite, intruded by diabase and basalt, and Troy sandstone underlie the watersheds. Surface soils are loam to clay-loam texture, with granular or crumb structure. Subsoils are layered and vary from clay loam to clay. The studies were conducted on relatively level areas at about a 7,200-foot (2,160-m) elevation.

The original forest consisted of ponderosa pine with some Douglas-fir, white fir, and large Gambel oak. Average basal area was 201 square feet per acre (46.2 m^2 per ha). New Mexican locust and Gambel oak were common in the understory and produced a dense stand after a wildfire in 1957 burned 60 acres (24.3 ha), eliminating the overstory. Ground cover now consists of seeded slender and intermediate wheatgrass, brome, Kentucky bluegrass, and bracken fern and geranium. The locust cover was about 10 feet (3 m) tall when the studies began. Stem diameters, measured at 6 inches (15 cm) above the ground surface, averaged 1.25 inches (3.1 cm).

Methods

Locust Control and Ponderosa Pine Regeneration

Locust control and ponderosa pine regeneration studies used a randomized block design with three blocks and five treatments per block. Each plot was 25 by 25 feet (7.5 by 7.5 m). The study was established in April 1967.

The five locust control treatments were:[3]

Treatment 1.—Cut stems during dormant season (early April) and paint stumps with 2,4-D amine (dimethylamine salt of 2,4-dichlorophenoxyacetic acid). Spray sprouts with 2,4,5-T ester (isooctyl ester of 2,4,5-trichlorophenoxyacetic acid) at 2 pounds a.e. per acre (2.2 kg a.e. per ha) in an oil-water emulsion.

Treatment 2.—Cut stems during growing season (June); paint and spray as in treatment 1.

Treatment 3.—Spray foliage during growing season (June) with 2,4,5-Tester in water at 2 pounds a.e. per acre (2.2 kg a.e. per ha) and spray sprouts as in treatment 1.

Treatment 4.—Cut stems during dormant season, paint stumps, but only spray sprouts in September.

Treatment 5.—Cut stems during dormant season; no initial or sprout herbicide applications.

The treatments, applied according to the schedule in table 1, were generally scheduled to take advantage of management herbicide applications on Workman Creek. This is one reason why amitrole (3-amino-1,2,4-triazole) at 3.1 pounds a.i. per acre (3.5 kg a.i. per ha) was substituted for 2,4,5-T on two occasions. Cut stems were removed from plots. The initial herbicide application for treatment 3 was applied with a backpack mist blower; all other broadcast treatments were applied with truck-mounted, motorized,

[3] *The study was conducted before the controversy about the safety of phenoxy herbicides such as 2,4,5-T. An emergency suspension was issued in March 1979 against the use of the herbicide on forest lands. A final decision has not been reached about the future registration of the herbicide.*

Table 1.—Schedule of herbicide treatments applied to New Mexican locust

Treatment	1967	1968		1969		1970
	Apr.	Jun.	Sep.	Jun.[1]	Sep.	Jun.[1]
1	X		X	X	X	X
2		X	X	X	X	X
3		X	X	X	X	X
4	X		X		X	
5	X					

[1]*Amitrole substituted for 2,4,5-T ester.*

high volume spray equipment. Foliage and stems were sprayed thoroughly to runoff.

The original treatment 5 plots (no herbicide) were inadvertently treated during an initial activity. New plots were established in an adjacent area which had similar precipitation, elevation, slope, and soils. History of the two sites was essentially similar. The relocation of treatment 5 compromises the randomized block design criteria, but it should not void the use of the model. Treatment effects were not compared with natural changes in an undisturbed locust stand. Stem counts were used to compare treatment effects.

Herbage production on each plot was determined by clipping randomly located 2-square-foot (0.18-m^2) subplots. Samples were oven-dried and weighed.

In March 1970, thirty-six 2-year-old ponderosa pine seedlings were planted in each of the 15 plots at a 5- by 5-foot (1.5- by 1.5-m) spacing. Because local seed was unavailable, trees were grown from seed collected at the same elevation in an adjacent tree seed-zone (Schubert and Pitcher 1973). The objective was to determine the effect of the pre- and post-planting herbicide applications on pine seedling survival. Seedlings were marked for future location and were checked periodically. Seedlings in very poor condition were counted as dead.

Soil Moisture

An unrelated study was established to determine if plant cover affected soil moisture through a growing season and if it would have implications for conifer regeneration. Gravimetric soil samples were collected by auger at approximately 2-week intervals from May 25 to October 5, 1976, from grass areas and from 5- and 20-year-old locust areas. Two sites which contained each of the three vegetation classes near each other were delineated in the main study area. Soil samples were taken in the spaces adjacent to grass plants and in the drip-line zone of the locust. Samples from locust sites were not collected from points with a heavy herbaceous layer. Three test holes were sampled from each vegetation type, in each site, for a total of 18 holes for every date. Four depths were sampled, 0-6 inches (0-15 cm), 6-12 inches (15-30 cm), 12-18 inches (30-45 cm), and 18-24 inches (45-60 cm). Soils were studied to 24 inches (60 cm), because ponderosa pine seedlings can grow a 20-inch (50-cm) tap root during the first season under optimum conditions (Schubert 1974). Standard bulk density measurements were made.

Results and Discussion

New Mexican Locust Control

The initial treatments in 1967 and 1968 were successful in eliminating the original brush overstory, but roots sprouted vigorously and some seeds germinated. The amount of sprouting was not significantly different among treatments. The average number of stems per plot increased from the original number of 58 ± 8 to 148 ± 18 prior to the September 1968 treatment.

Covariance analysis indicated significant changes ($p \leq 0.05$) when based on the pretreatment or the initial sprout locust stands. The five treatments can be divided into two groups based on the effectiveness of control. Individual comparisons between groups were significant; however, comparisons within groups generally were not.

Control at the end of the study (1971) was significantly better for the two dormant season stump treatments (1 and 4) and for the June foliage treatment (3), with an average of 14 ± 5 surviving stems per plot, than for the June stump treatment (2), and for the nonherbicide treatment (5), with an average of 79 ± 20 surviving stems per plot. This was true on either base. Differences were dramatic (fig. 3).

The two groups were also different after the September 1968 2,4,5-T application when based on the initial sprout stand. The average number of surviving stems per plot for treatments 1, 3, and 4 was reduced from 146 to 48 while the other treatments caused only slight changes. Control in 1971, based on the initial sprout stand, was slightly better in the dormant stump treatment which used both spring and fall sprout treatments (1) than in the dormant stump treatment which only used fall treatments (4) (a reduction from 104 to 9 surviving sprouts compared to a reduction from 202 to 19 sprouts). Although this indicates amitrole-related effects, 2,4,5-T appeared to produce better locust control.

The Spring 1970 inventory indicated significant differences between the nonherbicide treatment (5) (178 stems per plot) and treatments 1, 3, and 4 (average of 9 stems per plot) when based on pretreatment locust numbers. Fluctuations in treatment 5 results were caused by additional sprouting and natural mortality. High natural mortality has been reported for young black locust stands (Beck and McGee 1974), probably because locust is shade intolerant and suppressed sprouts do not survive long.

The initial 2,4,5-T treatment did not kill the locust root systems; however, they may have cumulatively contributed to the success of subsequent brush control. Bramble and Worley (1952) were able to eradicate black locust with a combination of a cut stub (stump) herbicide treatment and two annual foliage treatments. A combination of applications which did not include spraying the stubs was less effective. Bramble and Worley (1952) tested several herbicides including 2,4-D ester and 2,4,5-T ester. They also reported prolific sprouting after stub treatment.

The June stump treatment response was much different from the other spray treatments. Dormant season basal treatments of 2,4,5-T in oil (without cutting the stems) have proven effective against Gambel oak in Arizona (Johnson et al. 1969) and bear oak in Pennsylvania (Worley et al. 1957).

Dormant season applications were more effective than growing season applications in the latter experiment.

Foliage treatments might be preferred because they are easier to apply than are cut stump treatments. September applications of 2,4,5-T would be better than similar June treatments where ponderosa pine has already become established. Gratkowski (1977) reports that the pine is susceptible to 2,4,5-T damage in June but not in late August and September. This has also been observed at Workman Creek following management herbicide activities.

Cut stump treatments could be used on small areas or for spot applications. Use on larger areas would require heavy mechanical equipment (e.g., a bulldozer with a mounted spray rig). Such equipment can be directed to avoid areas with acceptable pine stocking.

Ponderosa Pine Regeneration

Ponderosa pine seedlings were checked in April and May 1970, but no survival differences among plots were found. Survival dropped from 66% in May to an unsatisfactory 21% in July, the main drought period in the Southwest. Analysis of July data indicated significantly better survival (39%) in the undisturbed locust sprout plots (treatment 5) than in two of the herbicide treatment plots (2 and 4) (12%). By October, overall ponderosa pine survival for all treatments was 9%; however, survival was significantly greater in treatment 5 (24%) than in the other four treatments (5%).

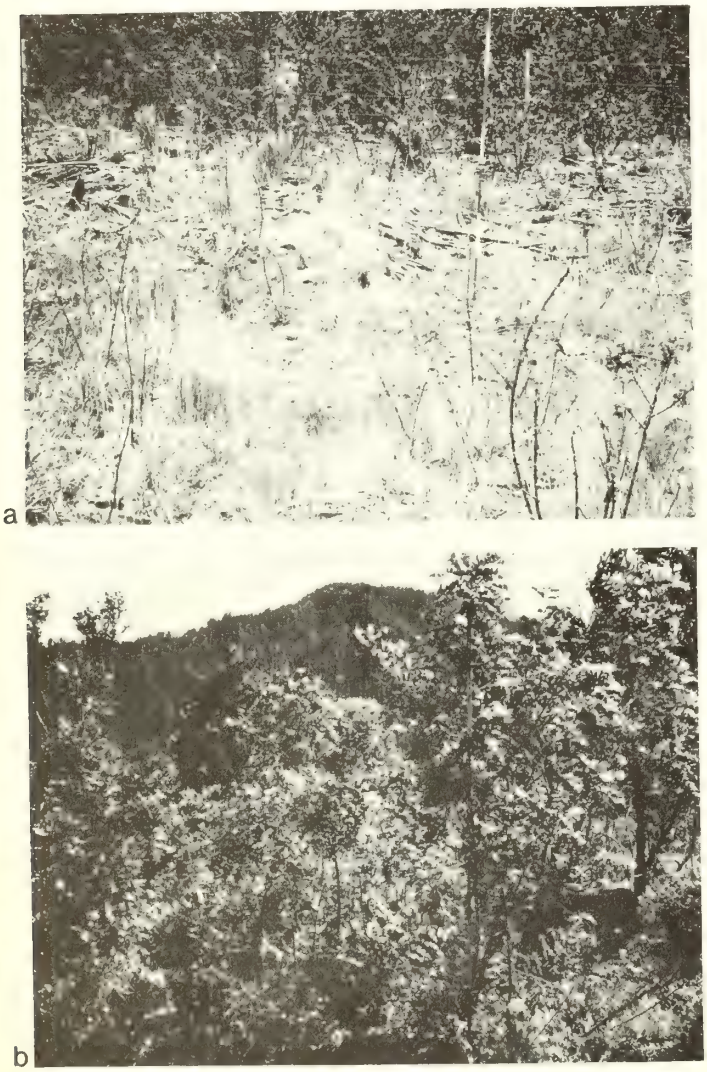


Figure 3.—A photographic comparison in June 1971 of (a) a typical plot where locust has been controlled, with (b) a nonherbicide plot. The range pole is 8 feet (2.4 m) tall.

Pine mortality appeared to be almost equally caused by drought and by pocket gophers (*Thomomys bottae*). Herbage production which would affect soil moisture availability for seedlings was similar for all treatments and averaged 1,000 ± 104 pounds per acre (1,120 ± 117 kg per ha). Ideally, this heavy cover should have also been controlled. Gopher damage was not significantly different among treatments.

Some amitrole damage to pine seedlings in the form of chlorotic pine needles was observed from the 1970 treatment, but a subsequent check did not indicate mortality.

Ponderosa pine survival was poor, and the site would have to be replanted under normal management. However, tree survival in treatment 5 (no sprout control) was comparatively good. It appears that seedling survival could be related to the locust and oak cover which affected seedling microclimate. However, the degree of shade is very important, especially for a shade-intolerant species. Seedlings growing in partial shade apparently do best, but too much shade is detrimental. Pearson (1950) found that more than 50% artificial overhead shade affected ponderosa pine survival. Overhead shade is more detrimental than side shade (Pearson 1950). On severe sites, some protection may improve initial survival. Shade may be particularly critical for newly planted seedlings, because they usually only have 30 to 45 days to adjust to the field before the late spring drought. The apparent benefits of brush cover were also observed in 1973 on South Fork, where 2-year-old ponderosa pine seedlings survived better in the partial shade of locust sprouts than in adjacent openings. Any measures which enhance seedling survival during the critical early years will improve the chances of achieving adequate stocking.

It is always best to establish ponderosa pine as soon as possible after a disturbance. Managers should take advantage of the temporary benefits of a partial locust cover by delaying brush control until the locust impedes pine development. An environmentally safe herbicide, which would not injure conifers, would provide such an option. Since the environmental safety of 2,4,5-T and other herbicides has recently been questioned, alternative herbicides need to be tested and registered before control recommendations can be made.

Soil Moisture

The results of this study cannot be used to explain the previous findings because of the time gap. The study showed significantly more moisture in the top 24 inches (60 cm) of soil under 5-year-old locust stands than in the grass stands (fig. 4). The differences between 5- and 20-year-old locust stands were significant 8 out of the 10 dates. Grass and 20-year-old locust stands had different soil moisture on seven dates. Soil moisture was generally greatest in the 5-year-old stands, intermediate in the grass, and lowest in the 20-year-old stands. Some exceptions to this ranking may be a result of sampling variation.

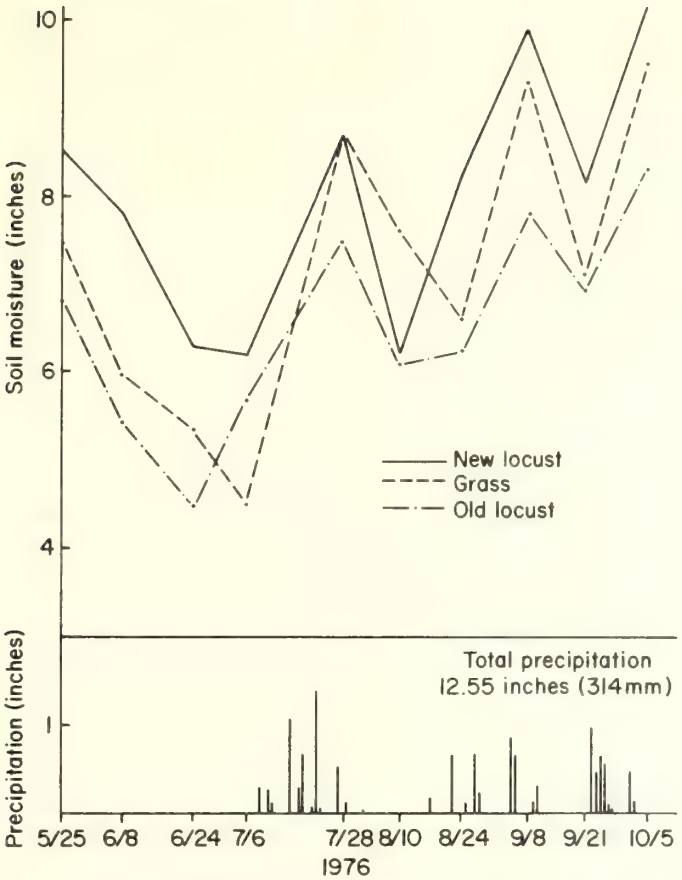


Figure 4.—Changes in moisture in the top 24 inches (60 cm) of soil under new locust, grass, and old locust. South Fork precipitation is shown at the bottom; 24.62 inches (616 mm) fell between October 1975 and May 1976.

Soil moisture for the area varied by depth during most of the season. The 0- to 6-inch depth had less soil moisture than the three lower depths, except after rain, when conditions were similar to the 6- to 12-inch depth. The 6- to 12-inch depth usually had less moisture than the two lowest depths, which were generally equal. All three vegetation types showed this relationship among depths.

More intensive research is necessary before any definite recommendations can be made. However, the additional soil moisture adjacent to young locust would benefit conifer regeneration. An understanding of the optimum spacing between locust and ponderosa pine is needed. Such information could be used to prepare guidelines for determining when control should be started and where conifer seedlings could be planted so that they would receive protection, especially when dead shade (i.e., logs) is not available.

Literature Cited

Beck, Donald E., and Charles E. McGee. 1974. Locust sprouts reduce growth on yellow-poplar seedlings. USDA Forest Service Research Note SE-101, 6 p. Southeastern Forest Experiment Station, Asheville, N.C.

Bramble, W. C., and D. P. Worley. 1952. Control of black locust with chemical sprays. Pennsylvania State College Progress Report 72, 5 p.

Coffman, Michael S. 1975. Shade from brush increases survival of planted Douglas-fir. Journal of Forestry 73:726-728.

Gratkowski, H. J. 1977. Seasonal effects of phenoxy herbicides on ponderosa pine and associated brush species. Forest Science 23:2-12.

Johnsen, Thomas N., Warren P. Clary, and Peter F. Ffolliott. 1969. Gambel oak control on the Beaver Creek pilot watershed in Arizona. U.S. Department of Agriculture, Agricultural Research Service, ARS-34-104, 8 p.

Little, Elbert L., Jr. 1950. Southwestern trees. U.S. Department of Agriculture, Agriculture Handbook 9, 109 p. Washington, D.C.

Little, Elbert L., Jr. 1976. Atlas of United States trees. Volume 3: Minor western hardwoods. USDA Forest Service Miscellaneous Publication 1314, 230 p. Washington, D.C.

Pearson, G.A. 1950. Management of ponderosa pine in the Southwest. U.S. Department of Agriculture, Agriculture Monograph 6, 218 p. Washington, D.C.

Ryker, Russell A., and Dale R. Potter. 1970. Shade increases first-year survival of Douglas-fir seedlings. USDA Forest Service Research Note INT-119, 6 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA Forest Service Research Paper RM-123, 71 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Schubert, Gilbert H., and John A. Pitcher. 1973. A provisional tree seed-zone and cone-crop rating system for Arizona and New Mexico. USDA Forest Service Research Paper RM-105, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Worley, D. P., W. C. Bramble, and W. R. Byrnes. 1957. Investigation of the use of 2,4,5-T esters as a basal spray in the control of bear oak. Weeds 5:121-132.

Youngberg, C. T. 1966. Silvicultural benefits from brush. Proceedings of the Society of American Foresters 1965:55-59.

Appendix

Common and Scientific Names of Plants

Bear oak	*Quercus ilicifolia* Wang.
Black locust	*Robinia pseudoacacia* L.
Bracken fern	*Pteridium aquilinum* var. *pubescens* Underw.
Brome	*Bromus* spp.
Douglas-fir (Rocky Mountain)	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Gambel oak	*Quercus gambelii* Nutt.
Geranium	*Geranium eremophilum* Woot. & Standl.
Intermediate wheatgrass	*Agropyron intermedium* (Host) Beaver.
Kentucky bluegrass	*Poa pratensis* L.
New Mexican locust	*Robinia neomexicana* A. Gray
Ponderosa pine	*Pinus ponderosa* Laws.
Slender wheatgrass	*Agropyron trachycaulum* (Link) Stend.
White fir	*Abies concolor* (Gord. & Glend.) Lindl.

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Agriculture—CSU, Fort Collins

Rocky Mountains | Southwest | Great Plains

Research Note RM-387

June 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Computer Techniques for Land Management Planning

Curtis M. Johnson[1]

UNIVERSITY LIBRARY
SEP 11 1980

A computer system for storage and retrieval of approximately 200 land management planning techniques for the Rocky Mountain and Southwestern Regions of the Forest Service has been placed on the USDA UNIVAC 1100 computer at Fort Collins, Colo. An abstract of each technique can also be retrieved from remote terminals via telephone.

Keywords: Computer programs, land management planning, information storage and retrieval

The Rocky Mountain and Southwestern Regions with the Rocky Mountain Forest and Range Experiment Station have assembled a list of computer-aided land management planning and assessment techniques. This list includes approximately 200 programs that can be searched by most functional and resource areas in a land management plan. An abstract of each technique is provided, which defines the technique and the circumstances or situations where it might be used. Both the list of techniques and their abstracts have been place on the USDA UNIVAC 1100/82 computer at Fort Collins, Colo.[2] Both are accessible via telephone service in an interactive mode to field personnel with remote terminals. Statements on execution are self-explanatory within the program.

Instructions to Execute

The runstream (a list of computer commands) in figure 1 provides the information needed to retrieve the planning assessment techniques from the Fort Collins Computer Center. An explanation of figure 1 is as follows:

```
Cols  12345678901234567890

1.    @RUN Run-id,ACCOUNT-NO,RMLMP
2.    @ASG,A RMLMP*ABSTRACT.
3.    @ADD RMLMP*ABSTRACT.RUN1
.     .
.     .
.     .
4.    @FIN
```

Figure 1.—Example runstream to access planning assessment techniques.

[1] *Technology Transfer and Applications Specialist, Rocky Mountain and Southwest Regions, located at the Rocky Mountain Forest and Range Experiment Station Forestry Science Laboratory at Flagstaff, in cooperation with Northern Arizona University. Headquarters is at Fort Collins, in cooperation with Colorado State University.*

[2] *The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a government-produced computer program. For cost information, write: Director, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, CO 80526.*

1. Sign on run statement giving a 6-digit run identification, a 10-digit account number, and the project identifier.
2. Assign statement to access the RMLMP* ABSTRACT file.
3. Statement which begins program operation.
4. Terminates run after retrieval.

Program Input and Output

Input required for execution of RMLMP* ABSTRACT is performed by first entering the numeric function code for the area of interest. After entering this four-digit numeric code, a table of assessment techniques will be given, listing the assessment name, whether the model is available from the Fort Collins computer or some other computer, whether a user's guide is available, whether the model is under development or needs further modification, and a very brief description of the technique (fig. 2).

After the programs are listed for a specific resource or functional area, users have the option of retrieving an abstract of a specific technique on their terminals or retrieving all the abstracts on a local high-speed printer. This is done by entering either ONE for one particular abstract or ALL to retrieve all the abstracts. A high-speed printer SITE-ID in the format FCRXXX has to be entered in conjunction with ALL. The abstract retrieved will provide information on the purpose and description of the program, its area of applicability, if it has been verified for use, data requirements, program outputs, the computer system where it is available, the organization responsible for its maintenance and support, a contact person for further information, and reference documentation. Figure 3 shows how to retrieve a specific abstract and an example of that abstract.

The RMLMP*ABSTRACT program will be continually updated as new models are developed or become operational, or informational or support people change.

```
ASSESSMENT TECHNIQUES FOR
LAND MANAGEMENT PLANNING
   (REGIONS 2 AND 3)
     AS OF 12/14/79
1600 (PUBLIC INVOLVEMENT)
1920 (ANALYSIS)
1960 (ECONOMICS)
2100 (CLIMATE)
2200 (RANGE)
2310 (RECREATION)
2380 (VISUAL)
2400 (TIMBER)
2500 (WATER)
2550 (EROSION)
2600 (WILDLIFE)
5100 (FIRE)
6630 (DATA MANAGEMENT)
7140 (DISPLAY)
7700 (ENGINEERING)
9888 (STATISTICAL)

ENTER NUMERIC FUNCTION CODE OR FINISH
START IN COLUMN 1.
>1600
```

12/14/79 ASSESSMENT TECHNIQUE - (PUBLIC INVOLVEMENT)

ASSESSMENT NAME	ABSTRACT IN FILE	STATUS OF TECHNIQUE: ON FCCC	ON ELSEWHERE	USER GUIDE AVAILABLE	NEEDS MODIFYING OR BEING DEVELOPED	DESCRIPTION
CLUSTER	YES	X		YES		DATA GROUPING
PUBLIC	YES	X		YES		ANALYSIS OF PUBLIC INPUT AND IDENTIFICATION OF PUBLICS
SELGEM	YES	X		YES		STORING, SORTING, RECALLING PUBLIC COMMENT

Figure 2.—Example of input and output of abstract list.

```
 DO YOU WANT AN ABSTRACT OF ONE OR MORE OF THE ASSESSMENTS
 LISTED FOR (PUBLIC INVOLVEMENT)
 ENTER YES OR NO
>YES
 YOU CAN SELECT MORE THAN ONE ASSESSMENT BY SUCCESSIVE INPUT
 SOLICITATIONS BY ENTERING THE COMMMAND: ONE
                          ---OR---
 YOU CAN PRINT -ALL- ASSESSMENTS FOR THE SELECTED FUNCTION BY
 ENTERING THE COMMAND: ALL. IF YOU ENTER ALL, YOUR OUTPUT WILL
 BE PRINTED ON A HIGH-SPEED PRINTER. YOU WILL NEED THE SITE-ID
 OF A HIGH-SPEED PRINTER NEAR YOU, AND INPUT THAT ID WHEN
 ASKED FOR IT.
 ENTER EITHER ONE OR ALL.
>ONE
 ENTER ASSESSMENT NAME OR FINISH
 START IN COLUMN 1.
>PUBLIC
                    PUBLIC INVOLVEMENT
 NAME: PUBLIC
 LONG NAME: PROCEDURE FOR PUBLIC INVOLVEMENT
 DESCRIPTION AND PURPOSE: A SERIES OF COMPUTER PROGRAMS, PRIMARILY
     MULTIVARIATE STATISTICAL TECHNIQUES, WHICH CLARIFIES THE
     COLLECTION AND ANALYSIS OF PUBLIC OPINION DATA, AND SHOWS HOW SUCH
     DATA CAN BE UTILIZED TO EXAMINE THE CORRESPONDENCE BETWEEN AGENCY
     STAFF SPECIALISTS AND VARIOUS PUBLIC OPINIONS SO THAT PROFESSIONAL
     ADVISE AND PUBLIC OPINION CAN-BE MORE HARMONIOUSLY MESHED.
 AREA OF APPLICABILITY: SERVICEWIDE
 DATA REQUIREMNNTS: WILL ACCEPT MANY DIFFERENT DATA FORMATS ON PUBLIC
     OPINION. ONE OPTION IS A RANK ORDER OF LAND USES AND THE ACTIVITY
     LEVEL DESIRED FOR EACH LAND USE VALUE.
 PROGRAM OUTPUTS: LISTING OF INPUT DATA AND INVALID INPUT DATA,
     DESCRIPTIVE STATISTICS AND HISTOGRAM REPRESENTING THE PERCENTAGE
     OF RESPONSES FALLING IN UP TO 13 DISTINCT CATEGORIES, KENDALL
     CONCORDANCE COEFFICIENT WITH OBSERVATIONS USED, A SINGLE PRIORITY
     RANKING OF THE VARIABLES SATISFACTORY TO THE MAJORITY OF
     INDIVIDUALS WHOSE PRIORITY RANKINGS COMPOSE THE DATA, AND A FACTOR
     ANALYSIS WITH STATISTICS, PLOTS, GROUP SORTING AND RANKINGS.
 SYSTEM/COMPUTER HARDWARE: UNIVAC 1100
 MODE SOFTWARE DEVELOPED FOR: BATCH, FIXED FIELD
 UNIT RESPONSIBLE FOR MAINTENANCE AND SUPPORT:
                              R-3, RO, LMP, ALBUQUERQUE, NM
 INFORMATION CONTACT PERSON: DON RENTON
               ORGANIZATION: LMP, RO, R-3
                              ALBUQUERQUE NM
                  TELEPHONE: FTS 474-3630
 DOCUMENTATION: CASE,P.J., T.D. EDGMON, D.A. RENTON. 1976. PUBLIC: A
     PROCEDURE FOR PUBLIC INVOLVEMENT. RANGE SCIENCE SERIES NO. 22,
     COLLEGE OF FORESTRY AND NATURAL RESOURCES, RANGE SCIENCE DEPT. CSU
 END OF (PUBLIC INVOLVEMENT)
 DO YOU WANT ANOTHER ASSESSMENT (YES OR NO)
>NO

 DO YOU WANT TO LIST ANOTHER FUNCTION (YES OR NO)
>NO
 END RUN
>
```

Figure 3.—Example of an abstract and how to retrieve it.

Rocky Mountains | Southwest | Great Plains

Research Note RM-388

August 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Development of Classes for Evaluating the Condition of Agricultural Conservation Program Conifer Plantings

William B. Kurtz,
Thomas J. Mills,
and
Ralph J. Alig[1]

JAN

Five classes were developed to categorize 10- to 15-year-old conifer stands by silvicultural condition. Sample stands whose planting was cost-shared under the Agricultural Conservation Program were selected from broad regions of the eastern one-half of the United States. Screening criteria were age, site index, conifer and hardwood basal area, and density.

Keywords: stand condition, Agricultural Conservation Program, stand management, plantation

Categorization of timber stands by silvicultural condition was an important aspect of a study of the retention rate and current condition of Agricultural Conservation Program (ACP) conifer plantings 10-15 years old (Kurtz et al. 1980). Development of stand condition categories (classes) was a unique part of the study made necessary by the general absence of established silvicultural and economic criteria for use in evaluating the management direction for these stands.

Sample stands were screened and divided into five condition classes, reflecting whether previous followup treatment had occurred and whether any future followup treatment was needed to enable a stand to attain its productive potential. The evaluation was used to determine whether plantings should be retained for timber growing, should be treated in the near future, or will not need treatment.

[1]*The authors are Associate Professor, University of Missouri, Columbia; Project Leader, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Riverside, Calif.; and Forester, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., respectively.*

Past Studies

Few studies have been conducted relating current stand condition to past management practices.

Dingle and Fletcher (1955) examined 1,419 farm tree plantings established between 1937 and 1948 from seedlings supplied by the Missouri Conservation Commission. They noted a positive relationship between planting survival and condition of planting stock, site condition prior to planting, suitability of planting method, and degree of plantation care. Only 11% of the plantings studied were judged to have received "good" care, while 47% had received "poor" care. Poor care included failure to provide protection from grazing, fire, and brush invasion. Survival ranged from 59% under good care to 35% under poor care.

The Tennessee Valley Authority (TVA), Division of Forestry Development (1962) surveyed 1,373 plantations established between 1934 and 1960 in the Tennessee Valley. Ten percent of these plantings had received ACP payments. Eighty-one percent of the plantations were still in existence. Eighty-five percent of the existing plantings were classified as having enough trees for successful timber production. Stocking was termed fair to good on over three-fourths of the existing plantings. While 17% were labeled as overstocked, only 4% were described as having poor stocking. Higher plantation success ratios (i.e., areas still in trees compared with areas planted) were associated with plantations that were never sold, were contract planted, and were planted on open land.

The extent, composition, and general condition of northern conifer plantations in the Northeast were examined by Kingsley and Mayer (1972). Nearly all of the poletimber and 76% of the sawtimber stands were greatly overstocked. Furthermore, many plantations suffered from hardwood invasion or needed pruning. Few cultural treatments had been applied after planting, particularly for private nonindustrial ownerships.

Williston and Dell (1974) found that, in Civilian Conservation Corps (CCC) pine plantations in northern Mississippi, only 8,005 (35%) of 22,575 acres planted to pine between 1934 and 1942 were still in plantations. Approximately 19% of the area had been invaded by hardwood species. Over the 10-year study period from 1959 to 1969, one-third of the area was clearcut prematurely. Most of that land was converted to pasture. Furthermore, roughly one-fourth of the area was understocked, with basal areas too low to adequately protect or fully utilize the sites.

Williston (1972) examined 3,875 pine plantations encompassing 66,095 acres on the Yazoo-Little Tallahatchie (Y-LT) Flood Prevention Project in north Mississippi. Fifteen percent of the total acreage had been taken out of plantations. Of those acres, 43% had been clearcut for posts or pulpwood, 28% cleared for pasture, 12% destroyed by fire, and 7% invaded by hardwoods.

Alig et al. (1980) found that, of the pine plantations initiated in the South under the Soil Bank Program from 1956 to 1960, 86% supported measurable volumes of growing stock. Many of the retained plantations were overstocked and in need of thinning, but only 5% were in poor condition. The average volume of growing stock measured on retained plantation acreage was over 22 cords per acre. An average of 6 cords per acre had been harvested from the original plantation acreage.

These studies indicate that followup treatments are not applied as frequently as needed on nonindustrial private lands. Since study methods varied and each study addressed a somewhat restricted geographic area, it is difficult to ascertain any consistent relationships between stand condition and past management practices.

Data Collection

Sampling Procedure

Sample states were selected from within broad regions of the eastern one-half of the United States based upon their representativeness and willingness to assist in the study. The sample states by region were Missouri (Central Region), Wisconsin (North Central Region), Pennsylvania (Northeast Region), South Carolina (Southeast Region), and Mississippi (South Central Region). Selecting individual states within these regions, rather than drawing samples from the entire region, greatly reduced travel time and the time spent contacting state forestry personnel. To maintain consistency, one person prepared measurements on all sample cases. Sampling in five states permitted this more easily than sampling regionwide.

Since these five states were willing to cooperate in the study and had records of plantings 10-15 years old, the quality of their state forestry agencies may be above average. If so, there may be a bias in the results toward higher retention and better condition than exists on the average. Furthermore, there may have been some bias in selection of the areas studied. For example, the average tract size within the counties sampled was generally greater than the statewide average tract size of ACP tree planting practices.[2]

A target sample of 50 cases, 10 acres or larger, per state was set. Within each state, 8-15 service forester areas were selected for sampling based on having large ACP workloads and retention of sufficient records. Three to twelve sample cases were then randomly selected in each service forester area. The number selected was in proportion to the number of ACP cases serviced by year for the service forester area. The sample age bracket had to be expanded from 10-15 years to 8-17 years of age to obtain a sufficient number of observations containing at least 10 planted acres.

[2]*Ensminger, R. K. 1977. Personal correspondence. USDA Agricultural Stabilization and Conservation Service, Washington, D.C. (on file at School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia.)*

Field evaluation of the selected case tracts by one of the authors (Alig) took place during the fall of 1976 and summer of 1977. A total of 312 tracts were examined, containing an original planted acreage of 6,320 acres.

Condition Data

The following data were gathered for each sample tract:

1. Current condition of conifer component: percent basal area in dominant and codominant crown position; and species data on density, basal area, and average diameter at breast height (d.b.h.).

2. Current condition of hardwood component: percent basal area in dominant and codominant crown position; evidence of suppression attempt; apparent age; and species data on density, basal area, and average d.b.h.

3. Current condition of understory component: density and total density by height class.

4. Subsequent timber activity: replanting (age, acres, species); precommercial thin (age, acres); hardwood control (age, acres, percent basal area removed); and timber harvest (age, acres, percent basal area removed).

Condition Class Development

Five condition classes were developed to screen the sample cases into management groups. Screening criteria were age, site index, conifer and hardwood basal area, and density.

Condition classes were developed for each of the following species groups found to be dominant on various sites: shortleaf pine (*Pinus echinata* Mill.); loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.); eastern white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), and jack pine (*Pinus banksiana* Lamb.); Norway spruce (*Picea abies* (L.) Karst.) and white spruce (*Picea glauca* (Moench. Voss.); European larch (*Larix decidua* Mill.) and Japanese larch (*Larix leptolepis* (Sieb. and Zucc.) Gord.); and Austrian pine (*Pinus nigra* Arnold). Criteria for the condition classes for these dominant species appear in table 1.

The various classes were developed from a search of pertinent literature as well as from a survey of individuals knowledgeable about management of the respective species groups. Because of the relative lack of yield information for intermediate treatments of certain conifer types, these expert opinions were particularly important. It must be remembered that these condition classes are based upon silvicultural guidelines which generally have not been subjected to verification by financial analysis. The exception to this is an investment analysis of the Mississippi samples drawn for this study.[3] That analysis indicated management of the Mississippi samples in nonretainable condition classes would produce negative present net worths at discount rates higher than 10% even if land costs were not included in the investment framework. A description of the stand condition classes follows:

Class 1: Do not retain.—This class contains stands which should not be retained for timber production because of an unacceptable low level of conifer stocking. Maximum conifer basal area and maximum conifer density limits were established by stand age group and site index range. Two maximum conifer densities were developed based on the average d.b.h. of conifer trees on the site.

Class 2: Do not retain.—Stands which contain an overabundance of hardwood stocking in relation to conifer stocking are placed in this class. In general, when hardwood stocking exceeded 50-55% of total basal area of the stand, the most sensible option was to not retain the remaining conifer component for timber production. In some cases, this relative excess of hardwoods was due to hardwood invasion after an initial low conifer stocking or after damage to the conifer component by fire, disease, or insects.

Class 3: Retain.—Stands in this class should be retained from a silvicultural standpoint, but will require a reduction in conifer stocking within 3-5 years in order to allow the stand to approximate its maximum possible yield. Minimum conifer basal area and minimum conifer density thresholds were established for each stand age group and site index.

Class 4: Retain.—Stands in this class should be retained, but will require hardwood removal within 3-5 years. If this treatment is not applied, a reduction in final conifer yield will occur. In general, this hardwood treatment is needed if hardwood stocking was from one-third to one-half of total basal area. An additional upper limit of from 160-200 free-growing conifer trees per acre, depending on principal conifer species, was established in order to more completely define this class.

Class 5: Retain.—Stands in this class need no silvicultural treatment for at least 3-5 years. Acceptable ranges for conifer basal area and conifer density were developed based on the upper and lower limits established for classes 1 and 3, respectively. Maximum acceptable hardwood stocking established in class 4 is an additional criterion which must be met.

[3]*Alig, Ralph J., William B. Kurtz, and Thomas J. Mills. 1980. The financial return of intermediate treatments in 8- to 15-year-old southern pine plantations varies with stand condition. Southern Journal of Applied Forestry. (manuscript in process).*

Table 1.—Description of condition classes

Species age	Site index	Class 1—Do not retain because of low conifer stocking[1]		Class 2—Do not retain because of high hardwood stocking	Class 3—Retain but treatment is required within 3-5 years because of high conifer stocking[2]		Class 4—Retain but treatment is required within 3-5 years because of high hardwood stocking	Class 5—Retain and no treatment is required for at least 3-5 years[1]	
		Maximum conifer basal area	Maximum conifer density	Maximum conifer basal area	Minimum conifer basal area	Maximum conifer density	Conifer basal area[3]	Conifer basal area	Maximum conifer density[4]
years	*height at 50 years*	*square feet per acre*	*trees per acre—diameter in inches*	*percent of total stand*	*square feet per acre*	*trees per acre*	*percent of total stand*	*square feet per acre*	*trees per acre*
Shortleaf pine[5]									
8-10	<50	30	150-3.5 or 250-2	50	95	1,300	50-67	30-95	1,300
	50-65	35	175-3.5 or 275-2	50	100	1,400	50-67	35-100	1,400
	66+	40	200-3.5 or 300-2	50	105	1,500	50-67	40-105	1,500
11-13	<50	40	130-4 or 230-2.5	50	105	1,200	50-67	40-105	1,200
	50-65	45	150-4 or 250-2.5	50	110	1,300	50-67	45-110	1,300
	66+	50	170-4 or 270-2.5	50	115	1,400	50-67	50-115	1,400
14-16	<50	50	110-5 or 210-3	50	115	1,100	50-67	50-115	1,100
	50-65	55	130-5 or 230-3	50	120	1,200	50-67	55-120	1,200
	66+	60	150-5 or 250-3	50	125	1,300	50-67	60-125	1,300
Loblolly and slash pine[6]									
8-10	<80	30	120-4 or 220-2.4	50	95	1,300	50-67	30-95	1,300
	80-100	35	150-4 or 250-2.5	50	100	1,400	50-67	35-100	1,400
	101+	40	180-4 or 280-2.6	50	108	1,500	50-67	40-108	1,500
11-13	<80	40	90-5 or 190-2.6	50	102	1,200	50-67	40-102	1,200
	80-100	45	100-5 or 200-2.7	50	110	1,300	50-67	45-110	1,300
	101+	50	110-5 or 210-2.8	50	118	1,400	50-67	50-118	1,400
14-16	<80	50	80-6 or 180-2.8	50	115	1,100	50-67	50-115	1,100
	80-100	55	90-6 or 190-2.9	50	120	1,200	50-67	55-120	1,200
	101+	60	100-6 or 200-3.0	50	128	1,300	50-67	60-128	1,300
White, red, and jack pine[7]									
8-10	<55	45	425-4 or 525-2.5	50	130	1,100	50-70	45-130	1,100
	55-75	50	450-4 or 550-2.5	50	135	1,200	50-70	50-135	1,200
	76+	55	475-4 or 575-2.5	50	140	1,300	50-70	55-140	1,300
11-13	<55	55	375-5 or 475-3	50	140	1,000	50-70	55-140	1,000
	55-75	60	400-5 or 500-3	50	145	1,100	50-70	60-145	1,100
	76+	65	425-5 or 550-3	50	150	1,200	50-70	65-150	1,200
14-16	<55	60	350-5.5 or 400-3	50	145	950	50-70	60-145	950
	55-75	65	375-5.5 or 450-3	50	150	1,050	50-70	65-150	1,050
	76+	70	400-5.5 or 500-3	50	155	1,150	50-70	70-155	1,150

	55-75	30	550-3 or 700-1.5	45	130	1,200	45-65	30-130	1,200
	76+	35	600-3 or 750-1.5	45	135	1,300	45-65	35-135	1,300
11-13	<55	30	500-3 or 650-1.5	45	135	1,000	45-65	30-135	1,000
	55-75	35	550-3 or 700-1.5	45	140	1,100	45-65	35-140	1,100
	76+	40	600-3 or 750-1.5	45	145	1,200	45-65	40-145	1,200
14-16	<55	35	400-3.5 or 550-2	45	140	900	45-65	35-140	900
	55-75	40	450-3.5 or 600-2	45	145	1,000	45-65	40-145	1,000
	76+	45	500-3.5 or 650-2	45	150	1,100	45-65	45-150	1,100
European and Japanese larch[9]									
8-10	<55	35	275-4 or 375-2.5	50	105	1,100	50-70	35-105	1,100
	55-75	40	300-4 or 400-2.5	50	110	1,200	50-70	40-110	1,200
	76+	45	325-4 or 425-2.5	50	115	1,300	50-70	45-115	1,300
11-13	<55	45	225-4.5 or 325-3	50	115	1,000	50-70	45-115	1,000
	55-75	50	250-4.5 or 350-3	50	120	1,100	50-70	50-120	1,100
	76+	55	275-4.5 or 375-3	50	125	1,200	50-70	55-125	1,200
14-16	<55	55	200-5 or 300-3.5	50	125	900	50-70	55-125	900
	55-75	60	225-5 or 325-3.5	50	130	1,000	50-70	60-130	1,000
	76+	65	250-5 or 350-3.5	50	135	1,100	50-70	65-135	1,100
Austrian pine[10]									
8-10	<55	40	375-3.5 or 450-2	50	125	1,100	50-67	40-125	1,100
	55-75	45	400-3.5 or 475-2	50	130	1,200	50-67	45-130	1,200
	76+	50	425-3.5 or 500-2	50	135	1,300	50-67	50-135	1,300
11-13	+55	50	325-4 or 400-2.5	50	135	1,000	50-67	50-135	1,000
	55-75	55	350-4 or 425-2.5	50	140	1,100	50-67	55-140	1,100
	76+	60	375-4 or 450-2.5	50	145	1,200	50-67	60-145	1,200
14-16	<55	55	275-5 or 350-3	50	145	900	50-67	55-145	900
	55-75	60	300-5 or 375-3	50	150	1,000	50-67	60-150	1,000
	76+	65	325-5 or 400-3	50	155	1,100	50-67	65-155	1,100

[1]*Planting characteristics must conform to both parameters in order to be placed in this class.*

[2]*Planting characteristics need only exceed one of the parameters in order to be placed in this class.*

[3]*Treatment would not be required if there are more than a certain number of free-growing conifer trees per acre. The threshold level is 175 for shortleaf pine; 160 for loblolly and slash pine; 200 for white, red, and jack pine; 225 for Norway and white spruce; 185 for European and Japanese larch; and 180 for Austrian pine.*

[4]*Minimum conifer density is threshold level specified for class 1.*

[5]*Sources: Personal communications—H. E. Garrett, School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia; N. F. Rogers, private forestry consultant, Salem, Mo. Literature—Brinkman and Rogers, 1967, Brinkman and Smith 1968, U.S. Department of Agriculture, Forest Service 1971.*

[6]*Sources: Personal communications—W. C. Anderson, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, La.; W. E. Balmer, U.S. Department of Agriculture, Forest Service, Southeast Area, State and Private Forestry, Atlanta, Ga.; M. Gaffney, South Carolina Commission of Forestry, Columbia; C. H. Morgan, Mississippi Forestry Commission, Jackson; R. Shackleford, U.S. Department of Agriculture, Forest Service, State and Private Forestry, Washington, D.C.; H. L. Williston, U.S. Department of Agriculture, Forest Service, Southeast Area State and Private Forestry, Jackson, Miss. Literature—Langdon and Trousdell 1974, Mann and Enghardt 1972, Mann and Lohrey 1974, U.S. Department of Agriculture, Forest Service 1971.*

[7]*Sources: Personal communications—J. W. Benzie, U.S. Department of Agriculture, Forest Service, Northern Conifers Laboratory, Grand Rapids, Minn.; W.S. Corlett, Pennsylvania Department of Environmental Resources, Harrisburg; A.L. Lundgren, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minn.; W. W. Ward, School of Forest Resources, Pennsylvania State University, University Park. Literature—Bartoo et al. 1963, Benzie 1977a, Benzie 1977b, Philbrook et al. 1973, Schlaegel 1971.*

[8]*Source: Frank and Bjorkbom 1973.*

[9]*Source: Douglass, R. W. 1961. The place of Japanese larch* Larix leptolepis *in Pennsylvania forestry. Unpublished M.S. thesis, Pennsylvania State University,* University Park.

[10]Source: Melton 1972

Note: Plantings may also be placed into nonretention classes because of fire, disease, insect, storm, or other damage that may be present in a planting along with low conifer stocking or high hardwood stocking.

Conditions of Stands

Tracts which should not be retained because of poor condition (condition classes 1 and 2) comprised 11% of the sample (table 2). An additional 43% were in retainable condition, but require some followup treatment within 3-5 years (condition classes 3 and 4). Conifer overstocking was the predominant reason followup treatments were required. This is consistent with the observations recorded by Kingsley and Mayer (1972), the Tennessee Valley Authority, Division of Forestry Development (1962), and Alig et al. (1980), all of which concluded that many of the stands examined were overstocked and in need of thinning. The remaining 41% of the sample cases require no treatment for at least 3-5 years (condition class 5). The range of cases in this class was from 31% in Missouri to 52% in South Carolina.

Site preparation had been applied to 62% of the cases in the do not retain classes. Since the need for site preparation is well documented, this would suggest that the amount or quality of site preparation in these cases was frequently inadequate, especially in controlling hardwood competition.

There was a close relationship between current stand condition and whether the original planting was an underplanting or not. Fifty-six percent of the underplantings were classified as being in nonretainable condition, which is over five times as large as the overall sample percentage (11%). There is considerable need for prompt release of underplantings from their overstory competition; the residual overstory was generally hardwood species. Unfortunately, not enough of the underplanted stands received this release. The conifer component in the average underplanting case was in noticeably poorer condition than it was in the average sample case. Even though there were usually sufficient conifer stems per acre (466), they had a smaller average d.b.h. (3.5 inches) than the all case conifer average of 4.4 inches and were competing with 195 hardwood trees that were 6.3 inches in d.b.h. A large percentage of the sampled understory plantings also had more hardwood basal area than conifer.

All harvests occurred in stands in the "retain" condition classes, and the majority occurred in stands that need no treatment within 3-5 years (condition class 5). It is logical that only well stocked stands were harvested, but the study results also show that the stands were not overcut so as to result in an insufficient residual conifer stocking.

Conclusions

Based on the condition classification, it was determined that a high percentage of the stands examined have the potential to attain desirable forest management goals. Eleven percent were in poor enough condition, because of

Table 2.—Percent of case tracts by condition class by state[1]

State	Class 1—Do not retain because of low conifer stocking	Class 2—Do not retain because of high hardwood stocking	Class 3—Retain but treatment is required within 3-5 years because of high conifer stocking	Class 4—Retain but treatment is required within 3-5 years because of high hardwood stocking	Class 5—Retain and no treatment is required for at least 3-5 years
	percent				
Missouri	0.0	17.3	42.3	7.7	30.8
Mississippi	0.0	7.8	42.2	9.4	34.4
South Carolina	1.6	4.7	28.1	9.4	51.6
Wisconsin	7.7	1.5	43.1	0.0	44.6
Pennsylvania	23.9	11.9	10.4	11.9	32.8
All sample states	5.4	5.4	36.9	6.0	41.3

[1]*Percent calculation is based on total number of cases for each state and all sample states.*

an overstocking of hardwoods or an understocking of conifers, that they should not be retained if the objective is timber production. An additional 43% of the retained cases should receive treatment within the next 3-5 years for them to approximate their maximum potential yield. The most widespread need (37%) is a thinning to reduce the conifer density, but 6% also need hardwood control. If these tracts are not treated, they may eventually slip into the nonretainable condition classes.

The overall lack of stand treatments after planting (e.g., hardwood removal) has led to over two-fifths of the tracts needing immediate treatments. Even though some underplantings were placed in a "treat but retainable" condition class, the cost of removing the large amount of hardwood basal area may lead to relatively low financial returns.

Literature Cited

Alig, Ralph J., Thomas J. Mills, and Robert L. Shackleford. 1980. Most Soil Bank plantings in the South have been retained; some need follow-up treatments. Southern Journal of Applied Forestry 4(1):60-64.

Bartoo, R. A., W. W. Ward, and Rex E. Melton. 1963. Early thinnings in a red pine plantation. Pennsylvania State University Forestry School Research Paper 33, 12 p. University Park.

Benzie, John W. 1977a. Manager's handbook for jack pine in the north central states. USDA Forest Service General Technical Report NC-32, 18 p. North Central Forest Experiment Station, St. Paul, Minn.

Benzie, John W. 1977b. Manager's handbook for red pine in the north central states. USDA Forest Service General Technical Report NC-33, 22 p. North Central Forest Experiment Station, St. Paul, Minn.

Brinkman, Kenneth A., and Nelson F. Rogers. 1967. Timber management guide for shortleaf pine and oak-pine types in Missouri. USDA Forest Service Research Paper NC-19, 15 p. North Central Forest Experiment Station, St. Paul, Minn.

Brinkman, Kenneth A., and Richard C. Smith. 1968. Managing shortleaf pine in Missouri. Missouri Agricultural Experiment Station Bulletin 875, 35 p. University of Missouri, Columbia.

Dingle, Richard W., and Peter W. Fletcher. 1955. A survey of forest tree plantings in Missouri. Missouri Agricultural Experiment Station Bulletin 640, 20 p. University of Missouri, Columbia.

Frank, Robert M., and John C. Bjorkbom. 1973. A silvicultural guide for spruce-fir in the Northeast. USDA Forest Service General Technical Report NE-6, 29 p. Northeastern Forest Experiment Station, Upper Darby, Pa.

Kingsley, Neal P., and Carl E. Mayer. 1972. The extent, composition, and general condition of northern conifer plantations in the northern region. 25 p. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pa. [presented at Conference on utilization of plantation grown northern softwoods, State University of New York, College of Environmental Science and Forestry, Syracuse University, Syracuse, September 6-7, 1969].

Kurtz, William B., Ralph J. Alig, and Thomas J. Mills. 1980. Retention and condition of Agricultural Conservation Program conifer plantings. Journal of Forestry 78(5): 273-276.

Langdon, O. Gordon, and Kenneth B. Trousdell. 1974. Increasing growth and yield of natural loblolly pine by young stand management. *In* Proceedings of the symposium on management of young pines. [Charleston, S.C., December 3-5, 1974] U.S. Department of Agriculture, Southeastern Area, State and Private Forestry, Atlanta, Ga. 349 p.

Mann, William F., Jr., and Hans G. Enghardt. 1972. Growth of planted slash pine under several thinning regimes. USDA Forest Service Research Paper S0-76, 10 p. Southern Forest Experiment Station, New Orleans, La.

Mann, William F., Jr., and Richard E. Lohrey. 1974. Precommercial thinning of southern pines. Journal of Forestry 72(9):557-560.

Melton, Rex E. 1972. Austrian pine plantation performance on the Stone Valley Experimental Forest. Pennsylvania Agricultural Experiment Station Progress Report 328, 10 p. Pennsylvania State University, University Park.

Philbrook, James S., James P. Barrett, and William B. Leak. 1973. A stocking guide for eastern white pine. USDA Forest Service Research Note NE-168, 3 p. Northeastern Forest Experiment Station, Upper Darby, Pa.

Schlaegal, Bryce E. 1971. White pine production best at high stocking. USDA Forest Service Research Note NC-115, 2 p. North Central Forest Experiment Station, St. Paul, Minn.

Tennessee Valley Authority, Division of Forestry Development. 1962. A report of 85,700 forest plantations in the Tennessee Valley. 8 p. Norris, Tenn.

U.S. Department of Agriculture, Forest Service. 1971. Thinning pine plantations in 1971 and after. Forest Management Bulletin, 6 p. Southeastern Area State and Private Forestry, Atlanta, Ga.

Williston, Hamlin L. 1972. The question of adequate stocking. Tree Planters' Notes 23(1):9-10.

Williston, Hamlin L., and Tommy R. Dell. 1974. Growth of pine plantations in north Mississippi. USDA Forest Service Research Paper S0-94, 15 p. Southern Forest Experiment Station, New Orleans, La.

Agriculture—CSU, Fort Collins

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-389

August 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Woody Fuel Particle Size and Specific Gravity of Southwestern Tree Species

Stephen S. Sackett[1]

JAN

Average squared diameters and specific gravities were determined for eight species of forest trees in Arizona and New Mexico. These figures are used to help estimate weights and volumes of dead, down forest fuels using the planar intersect method. Values in the 0- to 0.25-inch, 0.25- to 1-inch, and 1- to 3-inch-diameter size classes are given for natural and activity-generated (slash) fuels.

Keywords: fuel inventory, slash residues, forest fires

Introduction

The use of the planar intersect method for inventorying downed woody material (Van Wagner 1968; Brown 1971, 1974; Brown and Roussopoulos 1974) is a widely accepted means of determining weight, volume, and depths of forest residues. The technique is used by many state and federal agencies to evaluate both natural debris and activity-generated residues (fuels) for purposes of fuel and fire research and management planning, and to assess the utilization potential for these residue materials. In addition, the method provides an opportunity to use fuel data to predict fire behavior.

To effectively use the planar intersect method for fuel evaluation, certain physical characterictics must be known about the woody material being measured. These characteristics may vary among tree species, within and among size classes, and among regions of the country for the same species. Different stages of decay represent another variable. Most important of these are the values that represent the average squared diameter ($\overline{d^2}$) and specific gravities (s) for the species and size class of material being estimated. Anderson (1978) simplified field calculations of the planar intersect sampling technique by providing graphic aids. Brown and Roussopoulos (1974) included common Intermountain West and North Central tree species. Roussopoulos and Johnson (1973) established these factors for slash fuels of several Lake State's tree species. Bevins (1978) has established a $\overline{d^2}$ value for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) slash fuels in Washington. Ryan and Pickford (1978) defined $\overline{d^2}$ and s values for natural fuels of seven tree species common to the Blue Mountains of Oregon and Washington.

The purpose of the work described here was to establish $\overline{d^2}$ and s values for standard dead, down forest fuel size classes of southwestern tree species so that the planar intersect method could be more readily adapted to Southwest conditions. Anderson (1978) points out that estimates of fuel loads can be improved by assigning specific gravities for the timber type in which the inventory is being made. He also suggests adjustments for average squared diameter be made, when available, at least for computer processing of fuel data.

Methods

Measurements were made primarily in Arizona and New Mexico to establish the $\overline{d^2}$ and s factors in 26 stands

[1]*Research Forester, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Tempe, in cooperation with Arizona State University. Station headquarters is at Fort Collins, in cooperation with Colorado State University.*

on 8 different forests. More than 4,300 diameter measurements were taken on 8 tree species. Specific gravities (s) were determined on approximately one-half of the above samples. Random transects were established, and diameter measurements were made to the nearest 0.001 inch in three size class categories common to the planar intersect inventory, using a machinist's micrometer. Slash measurements were made in recently cut material. Every second sample measured was collected and returned to the laboratory for specific gravity determination. Specific gravity was determined by weighing the displacement of an air-dried sample in mercury (Hg) and applying this value plus the sample's oven dry (OD) weight using the following formula:

$$s = 13.5939 \frac{W_{OD}}{W_{Hg}}$$

where:

s = sample specific gravity
13.5939 = specific gravity of mercury
W_{OD} = oven dry weight of sample (grams)
W_{Hg} = weight of the volume of mercury displaced by the sample (grams)

Results and Discussion

Table 1 shows the average squared diameter findings for both natural and activity-generated (slash) fuel for species commonly found in the southwestern United States. Specific gravities are summarized in table 2. Tables 3 and 4 illustrate the $\overline{d^2}$ and s differences, respectively, between common species found in the Intermountain West (Brown and Roussopoulos 1974), the Blue Mountains of Oregon and Washington (Ryan and Pickford 1978), and the Southwest. No clear pattern of differences emerges from the summary of either the diameters or the specific gravities. Diameter differences range from 0% to 62%. Specific gravity ranges from 2% to 53%.

The effect of the combined $\overline{d^2}$ and s differences in predicted fuel loadings would result in four cases being heavier using Brown's (1974) figures, and eight cases being lighter. Using the eight common cases of Ryan and Pickford (1978), two cases would produce heavier loads and six cases lighter.

Table 1.—Average squared diameters ($\overline{d^2}$) for natural and slash fuel found in the southwestern United States

Diameter size class	Natural				Slash			
	Species[1]	$\overline{d^2}$	Standard deviation	Sample size	Species[1]	$\overline{d^2}$	Standard deviation	Sample size
inches		*square inches*		*number*		*square inches*		*number*
0-0.25	PP	0.0378	0.0139	370	PP	0.0471	0.0107	60
	AS	.0275	.0151	110	WF	.0319	.0138	60
	OA	.0217	.0156	80	WP	.0284	.0105	60
	WP	.0216	.0121	100	DF	.0239	.0178	60
	AF	.0191	.0156	60	AS	.0236	.0114	60
	S	.0142	.0136	180	AF	.0234	.0139	60
	DF	.0132	.0151	120	S	.0172	.0092	60
0.25-1	DF	.3718	.2628	119	DF	.3228	.2309	60
	OA	.3568	.2481	80	AF	.2947	.2430	60
	S	.3450	.2577	180	AS	.2624	.1770	60
	AS	.3226	.2378	110	PP	.2467	.1988	60
	WP	.2421	.2072	100	WF	.2432	.2523	60
	PP	.2366	.2180	369	WP	.2171	.1891	60
	AF	.2295	.1528	60	S	.2137	.1624	60
1-3	AS	3.468	2.457	110	PP	3.574	2.231	60
	DF	3.142	1.957	120	WF	2.759	1.844	60
	PP	2.967	1.827	371	DF	2.508	1.170	60
	OA	2.870	1.760	80	AS	2.208	1.258	60
	AF	2.411	1.910	60	WP	2.197	1.231	60
	S	2.237	1.180	180	S	1.915	0.550	60
	WP	2.208	1.392	100	AF	1.895	0.523	60

[1]*Species refers to those that are found in the Southwestern Region: PP = ponderosa pine (*Pinus ponderosa *Laws.); AS = aspen (*Populus tremuloides *Michx.); DF = Douglas-fir (*Pseudotsuga menziesii *var.* glauca *(Beissn.) Franco); S = Engelmann spruce (*Picea engelmanii *Parry) and blue spruce (*Picea pungens *Engelm.); AF = corkbark fir (*Abies lasiocarpa *var.* arizonica *(Merriam) Lemm.); WP = southwestern white pine (*Pinus strobiformis *Engelm.); WF = white fir (*Abies concolor *(Gord. & Glend.) Lindl.); and OA = Gambel oak (*Quercus gambelii *Nutt.)*

Table 2.—Specific gravities (s) for natural and slash fuel found in the southwestern United States

Diameter size class	Natural				Slash			
	Species[1]	s	Standard deviation	Sample size	Species[1]	s	Standard deviation	Sample size
inches				*number*				*number*
0-0.25	OA	0.582	0.090	32	AS	0.579	0.072	24
	DF	.526	.077	20	WP	.551	.048	24
	S	.480	.121	116	WF	.551	.236	24
	PP	.463	.104	140	PP	.540	.072	26
	AS	.422	.090	109	DF	.463	.131	22
	AF	.398	.142	58	S	.457	.152	54
	WP	.373	.107	30	AF	.356	.084	18
0.25-1	OA	.546	.109	35	WF	.596	.281	26
	DF	.534	.068	20	AS	.584	.040	23
	S	.519	.076	170	WP	.565	.076	24
	AF	.472	.100	54	DF	.555	.048	24
	WP	.466	.150	44	PP	.543	.050	24
	PP	.464	.062	139	AF	.478	.046	24
	AS	.404	.111	134	S	.471	.137	53
1-3	OA	.635	.119	70	WF	.541	.069	24
	DF	.574	.139	20	AS	.526	.052	21
	S	.519	.124	87	WP	.524	.068	24
	WP	.458	.056	37	AF	.523	.065	25
	AF	.428	.069	57	DF	.505	.049	25
	PP	.392	.078	85	PP	.502	.057	24
	AS	.390	.011	134	S	.472	.076	54

[1]*Species refers to those that are found in the Southwestern Region: PP = ponderosa pine (*Pinus ponderosa *Laws.); AS = aspen (*Populus tremuloides *Michx.); DF = Douglas-fir (*Pseudotsuga menziesii *var.* glauca *(Beissn.) Franco); S = Engelmann spruce (*Picea engelmanii *Parry) and blue spruce (*Picea pungens *Engelm.); AF = corkbark fir (*Abies lasiocarpa *var.* arizonica *(Merriam) Lemm.); WP = southwestern white pine (*Pinus strobiformis *Engelm.); WF = white fir (*Abies concolor *(Gord. & Glend.) Lindl.); and OA = Gambel oak (*Quercus gambelii *Nutt.)*

Table 3.—Natural fuel differences of average squared diameters ($\overline{d^2}$) for tree species common to the Southwest, the Intermountain West, and the Blue Mountains of Washington and Oregon

Species	Diameter size class	Average squared diameters ($\overline{d^2}$)				
		Southwest	Intermountain West[1]	Difference[2]	Blue Mountains[3]	Difference[4]
	inches	*square inches*	*square inches*	*percent*	*square inches*	*percent*
Ponderosa pine	0-0.25	0.0378	0.0342	+10	0.0356	+6
	0.25-1	.237	.238	0	.262	−10
	1-3	2.97	3.12	−5	—	—
Douglas-fir	0-0.25	.0132	.0122	+8	0.0143	−8
	0.25-1	.372	.304	+22	.230	+62
	1-3	3.14	2.87	+9	—	—
Spruce	0-0.25	.0142	.0122	+16	0.0192	−26
	0.25-1	.345	.304	+14	.280	+23
	1-3	2.24	2.87	−22	—	—
Subalpine fir (corkbark fir)	0-0.25	.0191	.0122	+57	0.0167	+14
	0.25-1	.230	.304	−24	.208	+11
	1-3	2.41	3.12	−23	—	—

[1]*Brown (1974), table 2*

[2]$\frac{\textit{Southwest — Intermountain}}{\textit{Intermountain}} \times 100$

[3]*Ryan and Pickford (1978), table 2*

[4]$\frac{\textit{Southwest — Blue Mountains}}{\textit{Blue Mountains}} \times 100$

Table 4.—Natural fuel differences of specific gravities (s) for tree species common to the Southwest, the Intermountain West, and the Blue Mountains of Washington and Oregon

Species	Diameter size class	Specific gravities (s)				
		Southwest	Intermountain West[1]	Difference[2]	Blue Mountains[3]	Difference[4]
	inches			*percent*		*percent*
Ponderosa pine	0-0.25	0.463	0.41	+12	0.41	+12
	0.25-1	.464	.51	−10	.51	−10
	1-3	.392	[5].40	−2	—	—
Douglas-fir	0-0.25	.526	.55	−4	.61	−13
	0.25-1	.534	.43	+23	.62	−14
	1-3	.574	[5].40	+44	—	—
Spruce	0-0.25	.480	.34	+41	.34	+41
	0.25-1	.519	.34	+53	.34	+53
	1-3	.519	[5].40	+30	—	—
Subalpine fir (corkbark fir)	0-0.25	.398	.41	−2	.41	−2
	0.25-1	.472	.40	+18	.40	+18
	1-3	.428	[5].40	+7	—	—

[1]*Brown (1974), table 4*

[2]$\frac{\text{Southwest — Intermountain}}{\text{Intermountain}} \times 100$

[3]*Ryan and Pickford (1978), table 2*

[4]$\frac{\text{Southwest — Blue Mountains}}{\text{Blue Mountains}} \times 100$

[5]*Brown (1974), p. 17*

Conclusions

Dead, down forest fuel loadings in the Southwest can be determined by the computer program DOFUINV[2] using the figures presented in tables 1 and 2. Brown (1974) illustrates how calculations are done manually. Appropriate $\overline{d^2}$ and s can be used from the tables 1 and 2. Greater than 3-inch-diameter, sound material specific gravities can be found in U.S. Department of Agriculture, Forest Products Laboratory (1974) or U.S. Department of Agriculture, Forest Service (1973). Rotten material greater than 3-inch diameter has a tremendous range of specific gravities. Brown's (1974) figure of 0.30 is adequate to use for all species.

Although the data for this note were gathered in Arizona and New Mexico, it is reasonable to assume the $\overline{d^2}$ and s factors would work equally well for southern Utah and southwestern Colorado.

Literature Cited

Anderson, Hal E. 1978. Graphic aids for field calculation of dead, down forest fuels. USDA Forest Service General Technical Report INT-45, 21 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Bevins, Collin D. 1978. Fuel particle diameters of western hemlock slash. USDA Forest Service Research Note INT-243, 3 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Brown, James K. 1971. A planar intersect method for sampling fuel volume and surface area. Forest Science 17:96-102.

Brown, James K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report INT-16, 24 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Brown, James K., and Peter J. Roussopoulos. 1974. Eliminating biases in the planar intersect method for estimating volumes of small fuels. Forest Science 20(4): 350-356.

Roussopoulos, Peter J., and Von J. Johnson. 1973. Estimating slash fuel loading for several Lake States tree species. USDA Forest Service Research Paper NC-88, 8 p. North Central Forest Experiment Station, St. Paul, Minn.

Ryan, Kevin C., and Stewart G. Pickford. 1978. Physical properties of woody fuels in the Blue Mountains of Oregon and Washington. USDA Forest Service Research Note PNW-315, 10 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

U.S. Department of Agriculture, Forest Service. 1973. Silvicultural systems for the major forest types of the United States. U.S. Department of Agriculture, Agriculture Handbook 445, 124 p. Washington, D.C.

U.S. Department of Agriculture, Forest Products Laboratory. 1974. Wood handbook: Wood as an engineering material. U.S. Department of Agriculture, Agriculture Handbook 72 (revised), 414 p. Washington, D.C.

Van Wagner, C. E. 1968. The line intersect method in forest fuel sampling. Forest Science 14:20-26.

[2]*DOFUINV is a computer program taken from DFINV (NFFL program) and modified for use in southwestern forest stands. It is designed for use on an 1100 Univac computer. A copy of the program can be requested from: Fuel Management Project, USDA Forest Service, Forestry Sciences Laboratory, Arizona State University Campus, Tempe, AZ 85281.*

Mountains Southwest Plains

Research Note RM-390

September 1980

USDA Forest Service
Rocky Mountain Forest and
Range Experiment Station

Design and Construction of a Miniature Solar Power System to Operate Meteorological Instruments

Kenneth G. Bird[1]

The relatively inexpensive solar power system improves meteorological instrument reliability by maintaining an optimum operating voltage. System voltage and charging capabilities are easily modified to fit specific power requirements for other low-voltage applications.

Keywords: Meterological instruments, solar power

Size D, nonrechargeable batteries are often used to power meteorological instruments at remote locations. Low battery voltage, particularly during extremely cold weather, is a major cause of instrument failure, and thus, of record loss. This problem has been eliminated by changing from nonrechargeable batteries to a power pack, trickle-charged by a mini-solar panel. The system will provide more than 100 mA per day at 4 V, or enough power to operate up to 10 electric clocks.

Components

Solar Panel

The solar panel is constructed from small silicon chips that convert sunlight into electrical energy (fig. 1). Each 2- by 2-cm chip has an output rating of 100 mA at 0.45 V. Nine chips are connected in series to charge batteries to about 4 V. A diode must be placed in the circuit to prevent battery discharge through the solar panel when charging voltage is less than battery voltage. The solar cells begin to generate electricity when solar energy levels reach about 10% of full midday radiation. Some charging occurs even during cloudy weather.

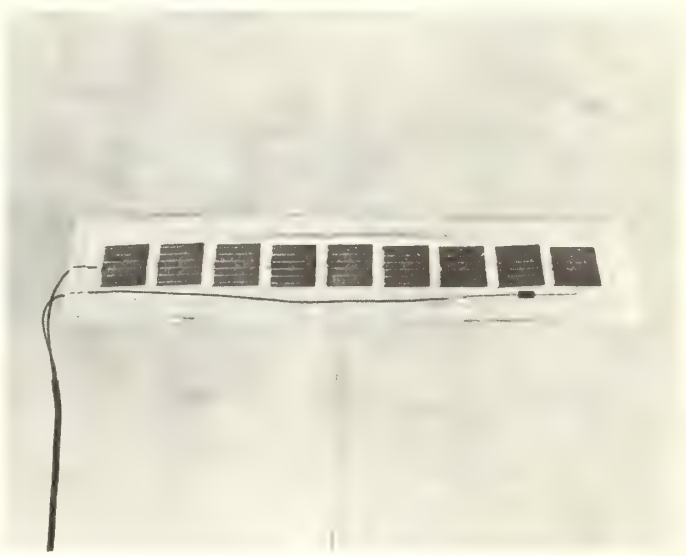


Figure 1.—Miniature solar panel showing location of blocking diode in lead wires to battery pack.

[1]*The author is a Range Technician, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, with headquarters at Fort Collins in cooperation with Colorado State University.* *Research reported here was conducted at the Station's Research Work Unit at Laramie, Wyo., and was supported in part by the Bureau of Land Management, U.S. Department of the Interior.*

Battery Pack

The battery pack stores electrical energy converted by the solar panel. It consists of three, D-sized, nickel-cadmium, rechargeable batteries connected in series; battery spring contacts, and a weatherproof container. Because nickel-cadmium batteries with a 4-Ah rating have a much longer service life, they are suggested for use in the battery pack instead of smaller capacity batteries. Batteries with a 1.2-Ah capacity began to fail after 1 year in field service.

Electric clocks used in meteorological instruments have an average current drain of about 0.35 mA or 8.4 mAh per day. The solar panel has an average output of about 100 mAh on an average winter day in southern Wyoming. Therefore, the system will operate about 10 electric clocks indefinitely in this area. Exact capabilities of the system, however, depend upon the solar regime at a particular site. For applications where power consumption exceeds the equivalent of 10 electric clocks, adding 1 more silicon chip to the series string will provide enough additional charging current to operate approximately 5 more electric clocks.

System Assembly

Solar Panel

Step 1.—Connect the nine silicon chips in series by soldering a short piece (about 1 cm) of stranded, no. 26 copper wire from the positive side of one chip to the negative side of the adjoining chip (fig. 2). Using the short piece of wire to connect chips results in a gap of 2-3 mm between them, which allows each chip to independently expand and contract as temperature changes. The wire need not be insulated. All connections should be thoroughly cleaned before and after soldering to insure a solid bond and prevent corrosion. Use only rosin core solder.

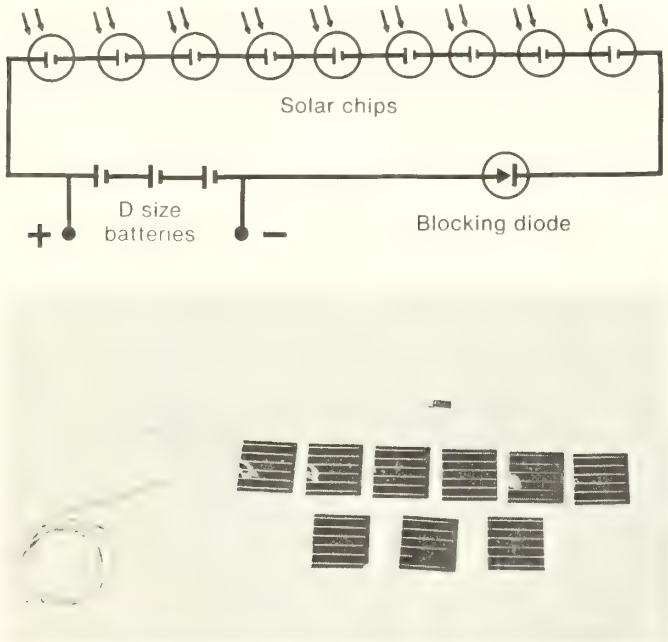


Figure 2.—(a) Schematic diagram of solar power system. (b) Materials needed for construction of a miniature solar panel. Individual cells in the top row have been connected in series; individual solar cells and the placement of an interconnecting wire between individual cells is visible in the lower row.

Step 2.—Solder the diode's anode lead to the positive end of the silicon chip string.

Step 3.—Solder 50 cm of no. 26, insulated, stranded, copper wire to the cathode lead of the diode and another 50 cm of wire to the negative end of the silicon chip string. Color coded wires aid in identifying positive and negative ends of the solar panel.

Step 4.—Center a thin strip of clear silicone seal along the center of a 5- by 23-cm sheet of Plexiglas. Center the silicon chip string above the Plexiglas sheet and gently press the back side of the string into the silicone seal.

Step 5.—Apply a bead of silicone seal around the perimeter of the Plexiglas, thick enough to extend above the surface of the solar chips. The two lead wires from solar chips exit the panel at one end and are positioned so that they do not obstruct the surface of any chip.

Step 6.—Center the second 5- by 23-cm sheet of Plexiglas over the first sheet, and then press down to compress the bead of silicone seal applied to the bottom sheet of Plexiglass in step 5. The silicone seal should be thick enough to prevent the top sheet of Plexiglas from touching the silicon chip string and will form a watertight seal.

Step 7.—Allow the seal to dry for 24 hours.

Step 8.—Attach an adjustable mounting bracket to the back of the solar panel for tilt adjustment. A small hinge with the pin replaced by a bolt and nut works well.

Battery Pack

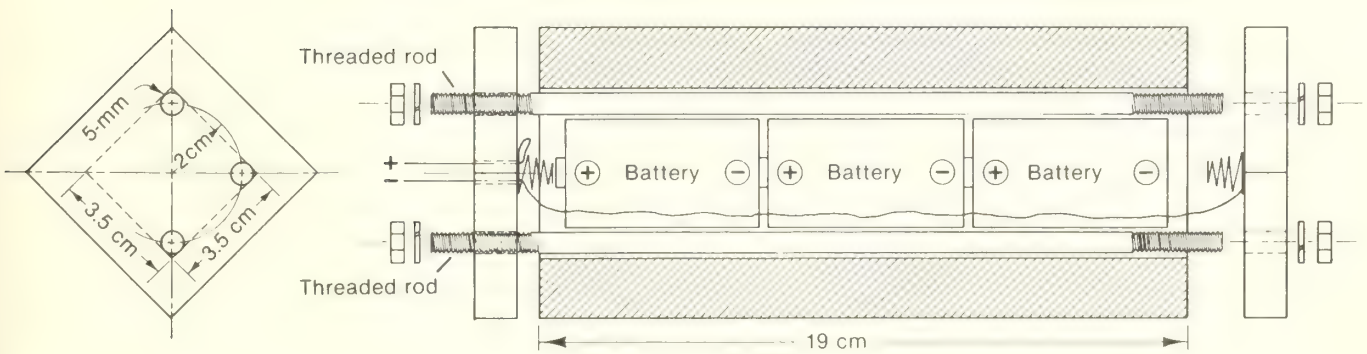
Step 1.—Cut and assemble four pieces of wood, plastic, or other suitable nonconducting construction material to form a waterproof container with inside dimensions of 3.5 by 3.5 by 19 cm (fig. 3).

Step 2.—Cut two end pieces the same size as the outside dimensions of the container.

Step 3.—Drill two holes 5 mm in diameter in each end piece for the threaded rods which hold the battery pack together. Holes are located 2 cm from the center of the end piece, on a diagonal towards opposite corners (fig. 3). A third hole, large enough for lead wires from the battery, is drilled in one end piece. This hole is also placed 2 cm from the center of the end piece, on a diagonal towards one of the remaining corners.

Step 4.—Solder 50 cm of no. 26, insulated, stranded copper wire to each battery spring contact. Glue a battery spring contact to the center of each end piece.

Figure 3.--(a) Photo of completed battery pack. (b) Diagram of battery pack, spring contact, threaded rod, and rechargeable size D batteries.



Step 5.—Permanently attach the end piece containing the two holes for threaded rods to the battery box. The battery contact should face the interior of the box. The lead wire extends through the interior of the box.

Step 6.—Insert three fully charged batteries into the box in series. Run both battery leads through the third hole in the end piece not attached to the box. Insert the two threaded rods through the permanently attached end piece and down the length of the box. The remaining end piece is then securely bolted to the box so that the battery is in contact with the spring contact.

Step 7.—Check battery leads for proper voltage and polarity.

Step 8.—Caulk all holes with silicone seal and paint the battery pack, if desired.

Field Installation of the Solar System

The solar panel must be installed where no obstructions block solar radiation and above the maximum snow accumulation level (fig. 4). The solar panel and battery pack lead wires are connected observing proper polarity. The final step in placing the solar power system into service is to connect it with electric clocks that operate meteorological instruments. The clocks may be connected directly to the power pack, but a more serviceable arrangement is to make the connection at a terminal block. The use of a terminal block simplifies connection or removal of meteorological instruments from the power pack, especially if more than one instrument is in use.

The solar panel is mounted with the solar chips facing south and the longitudinal axis oriented in an east-west direction. The exact southerly tilt of the panel from horizontal is not important except at installations where power consumption approaches maximum charging capacity of the panel in winter. An average setting for the central section of the United States is to tilt the panel face 45° from horizontal in a southerly direction. The panel can be aligned more precisely by tilting it 1° from horizontal for each degree of latitude at the installation site. The optimum alignment for year-round power generation must be done on-site, at noon, at the vernal or autumnal equinox, using a milliammeter. The meter is connected in series with the output lead from the solar panel. The southerly tilt of the panel is then adjusted for maximum current output.

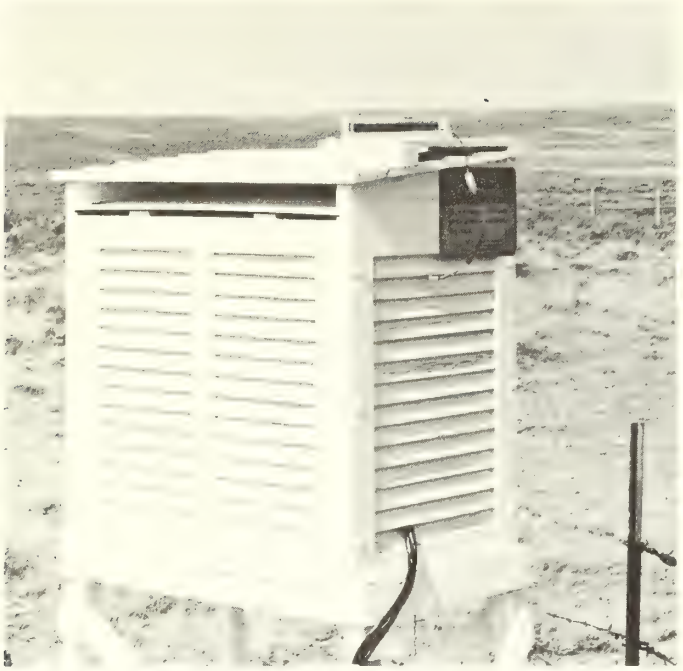


Figure 4.—Field installation of miniature solar panel on the roof of a weather bureau instrument shelter.

List of Materials[2]

Quantity	Item	Cost
3	Eveready CH4 battery or equivalent @ $6.32	$18.96
9	solar chip 2 cm² @ $1.49	13.41
2	3-mm-thick, clear Plexiglas sheet 5 by 23 cm	2.50
1	tube clear silicone seal	2.50
1	1N4000 series diode	0.25
2	battery spring contact @ $0.25	.50
2	25 cm length of 5 mm continuously threaded rod @ $0.25	.50
4	5 mm nut and washer @ $0.05	.20
1	2 m length of no. 26, insulated, stranded, copper wire	.25
1	25 cm length of rosin core solder	.10
	Total cost	$39.17

[2]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.*

Plant a tree! Mark the 75th birthday of the Forest Service by giving a living gift to future generations.

lountains Southwest Plains

Research Note RM-391

September 1980

USDA Forest Service

ERRATA FOR

USDA Forest Service Research Note RM-391

Some Mountain Pine Beetle Infestation Characteristics
in Dwarf Mistletoe-Infected and Uninfected Ponderosa Pine
by William F. McCambridge

On page 2, in table 1, under "Statistical significance," the "Egg gallery lengtH" should read "P<0.03."

There were no significant differences in attacks or brood production between heavily infected and uninfected trees. Total egg gallery length per unit of bark area was greater in uninfected trees.

Keywords: *Dendroctonus ponderosae, Pinus ponderosa, Arceuthobium vaginatum* subsp. *cryptopodum*

Ponderosa pines (*Pinus ponderosa* Laws.) that are heavily infected with dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens) grow at a slower rate than uninfected trees (Hawksworth 1977.) In lodgepole pine (*Pinus contorta* Dougl.), heavy mistletoe infection results in thinner phloem and reduced mountain pine beetle (*Dendroctonus ponderosae* Hopkins) brood production (Amman 1972, Roe and Amman 1970, McGregor 1978). Similar brood reduction might be expected in ponderosa pine.

This note examines mountain pine beetle brood and beetle attack densities, and total egg gallery length per unit area in ponderosa pine, shortly before beetle emergence. These infestation characteristics from trees with heavy dwarf mistletoe infection are compared to those in trees free of mistletoe.

Methods

Mountain pine beetle attacks, egg gallery length, and brood were counted from sample trees with dwarf mistletoe ratings of either 5 or 6 on the 6-class scale (Hawksworth 1977). A bark sample, 15 by 30 cm, was taken at breast height from both the north and south sides of each of 100 trees. Similar samples were taken from 100 trees uninfected by mistletoe and situated as close as possible to the sampled infected trees. An effort was made to sample trees of similar diameters.

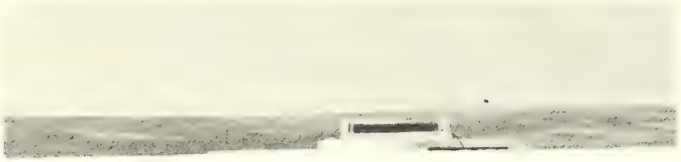
The bark samples were taken from trees widely distributed throughout the central portion of the Roosevelt National Forest in north-central Colorado. Data were collected during June 1978 and were subjected to analysis by "t" tests.

Results

Mountain pine beetle broods and attack density were not statistically different between heavily infected and uninfected trees. Total length of egg galleries per unit of bark area was approximately 10% greater in uninfected trees (table 1).

The brood densities obtained from trees with and without mistletoe were associated with declining beetle infestations.

[1]*Entomologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is at Fort Collins, in cooperation with Colorado State University.*



List of Materials[2]

Quantity	Item	Cost
3	Eveready CH4 battery or equi-	$18.96

...installation of miniature solar panel on the roof of a weather bureau instrument shelter.

...approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Plant a tree! Mark the 75th birthday of the Forest Service by giving a living gift to future generations.

Mountains Southwest Plains

Research Note RM-391

September 1980

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Some Mountain Pine Beetle Infestation Characteristics in Dwarf Mistletoe-Infected and Uninfected Ponderosa Pine

William F. McCambridge[1]

There were no significant differences in attacks or brood production between heavily infected and uninfected trees. Total egg gallery length per unit of bark area was greater in uninfected trees.

Keywords: *Dendroctonus ponderosae, Pinus ponderosa, Arceuthobium vaginatum* subsp. *cryptopodum*

Ponderosa pines (*Pinus ponderosa* Laws.) that are heavily infected with dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens) grow at a slower rate than uninfected trees (Hawksworth 1977.) In lodgepole pine (*Pinus contorta* Dougl.), heavy mistletoe infection results in thinner phloem and reduced mountain pine beetle (*Dendroctonus ponderosae* Hopkins) brood production (Amman 1972, Roe and Amman 1970, McGregor 1978). Similar brood reduction might be expected in ponderosa pine.

This note examines mountain pine beetle brood and beetle attack densities, and total egg gallery length per unit area in ponderosa pine, shortly before beetle emergence. These infestation characteristics from trees with heavy dwarf mistletoe infection are compared to those in trees free of mistletoe.

Methods

Mountain pine beetle attacks, egg gallery length, and brood were counted from sample trees with dwarf mistletoe ratings of either 5 or 6 on the 6-class scale (Hawksworth 1977). A bark sample, 15 by 30 cm, was taken at breast height from both the north and south sides of each of 100 trees. Similar samples were taken from 100 trees uninfected by mistletoe and situated as close as possible to the sampled infected trees. An effort was made to sample trees of similar diameters.

The bark samples were taken from trees widely distributed throughout the central portion of the Roosevelt National Forest in north-central Colorado. Data were collected during June 1978 and were subjected to analysis by "t" tests.

Results

Mountain pine beetle broods and attack density were not statistically different between heavily infected and uninfected trees. Total length of egg galleries per unit of bark area was approximately 10% greater in uninfected trees (table 1).

The brood densities obtained from trees with and without mistletoe were associated with declining beetle infestations.

[1]*Entomologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is at Fort Collins, in cooperation with Colorado State University.*

Table 1.—Comparison of mountain pine beetle (MPB) infestation characteristics in 100 pines heavily infected by dwarf mistletoe with 100 uninfected ponderosa pines, Roosevelt National Forest, 1978

Characteristics	Infected means	Uninfected means	Statistical significance
d.b.h. (cm)	29.8	30.8	NS
MPB per 9 dm^2	17.1	19.0	NS
Attacks per 9 dm^2	6.9	7.4	NS
Egg gallery length (cm) per 9 dm^2	247.1	270.1	P≤0.03

Agents causing beetle outbreak decline could conceivably mask initial brood differences if they do exist. This point is academic. However, broods should be investigated during early outbreak development to determine if mistletoe has an effect, not only on tree growth, but also on beetle broods.

There was no correlation between brood density and d.b.h., which is consistant with our previous brood sampling experience.

Mean beetle density of 23.9 per 9 dm^2 on the north side of trees was significantly greater than 12.2 per 9 dm^2 on the south sides ($P<0.01$). Blackman (1931) observed similar north-south brood differences in ponderosa pine on the Kaibab Plateau, Arizona, as did Beal and DeLeon[2] in southern Wyoming. Reid (1963) reported similar relationships in lodgepole pine.

Beetle attack density was similar on both sides of the trees.

[2] *Unpublished progress report of a study of the Black Hills beetle in southeastern Wyoming and central Colorado, summer of 1937. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 1938.*

Literature Cited

Amman, Gene D. 1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. Journal of Economic Entomology 65:138-140.

Blackman, M. W. 1931. The Black Hills beetle (*Dendroctonus ponderosae* Hopk.). New York State College of Forestry at Syracuse University Bulletin 4(4), Technical Publication 36, 97 p.

Hawksworth, Frank G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service General Technical Report RM-48, 7 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

McGregor, Mark D. 1978. Management of mountain pine beetle in lodgepole pine stands in the Rocky Mountain area. p. 129-139. *In* Theory and practice of mountain pine beetle management in lodgepole pine forests: Proceedings of the symposium. [Pullman, Wash., April 25-27, 1978]. Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow, in collaboration with USDA Forest Service, Forest Insect and Disease Research, Washington D.C., and the Intermountain Forest and Range Experiment Station, Ogden, Utah.

Reid, R. W. 1963. Biology of the mountain pine beetle, *Dendroctonus monticola* Hopkins, in the East Kootenay Region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. Canadian Entomologist 95:225-238.

Roe, Arthur L., and Gene D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA Forest Service Research Paper INT-71, 23 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Plant a tree! Mark the 75th birthday of the Forest Service by giving a living gift to future generations.

Agriculture—CSU, Fort Collins

Mountains Southwest Great Plains

Research Note RM-392

October 1980

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Reducing Natural Ponderosa Pine Fuels Using Prescribed Fire: Two Case Studies

CLEMSON UNIVERSITY LIBRARY
APR 21 1981
SCI., TECH. & AGR. DIV.

Stephen S. Sackett[1]

Dead, natural fuels were reduced in weight by 65% and 48%, respectively, when burned under different conditions in two ponderosa pine stands in Arizona. Fine surface fuel reductions temporarily lessen the threat of rapidly spreading wildfires. Large fuels were not as effectively altered by a single prescribed fire.

Keywords: Prescribed burning, hazard reduction, ponderosa pine, natural fuel loading

Management Implications

Prescribed burning is a useful tool for reducing fuel hazards in ponderosa pine. Surface fuels can be largely eliminated by burning under appropriate fall weather and fuel moisture conditions. Reduction of these ground and surface fuels can effectively temper fire behavior in the event of a wildfire, but with an annual rate of needle litter accumulation in the range of 900-1,400 pounds per acre per year,[2] interval burning is needed to prevent excessive fuel buildups.

Large fuels, to be completely consumed, require a considerable period of drying weather in late summer and fall to remove moisture from the interior of the log, and dry conditions just prior to burning to insure that the outside surfaces are dry enough to ignite and burn. If a substantial percentage of this heavy material can be removed with the first fire, subsequent interval burning will need to contend only with that portion of ground and surface fuels that accumulates annually. In that way, interval burning can be applied more safely and effectively.

This research provides a clear picture of what fuels are available to burn and in what amounts in typical ponderosa pine forests of the Southwest. Just what the appropriate intervals are for using fire in these stands is a subject of continuing research at Chimney Spring and Limestone Flats.

Introduction

Although hazard reduction is often the primary objective for burning, the potential for wildlife habitat improvement, range improvement, seedbed and site preparation, increased water yield, species composition change, and stand thinning are all additional benefits of fire in Arizona ponderosa pine stands.

Some reports have been made on the reduction of southwestern ponderosa pine fuels using prescribed fire. Truesdell (1969) suggests that one prescribed fire protects stands on the Fort Apache Indian Reservation from the damage possible from wildfire for 7 years. Davis et

[1] *Research Forester, Rocky Mountain Forest and Range Experiment Station. Headquarters is at Fort Collins in cooperation with Colorado State University. Research was conducted at the Station's Research Work Unit at Tempe in cooperation with Arizona State University.*

[2] *Report on file, Fuel Management Project, RM-2108, Tempe, Ariz.*

al. (1968) reported reductions of 33% and 36% in natural ponderosa pine fuels in Arizona that had fuel loads of 10.2 and 17.6 tons per acre of fuel, respectively. Cooper (1961) reports surface fuels (L layer) were completely consumed in a prescribed fire on the Fort Apache Indian Reservation and ground fuels (F and H layers) were reduced by 15% with an original weight of 35.3 tons per acre. Gaines et al. (1958) measured the fuel reduction from two fall prescribed fires on the same Indian reservation. They found reductions of 48% and 50% in 0- to 2-inch-diameter class material with original loads of 6.2 and 4.8 tons per acre, respectively. The fires reported above were not done under the same conditions or in the same stands. Therefore, they cannot be usefully compared. However, the surface fuels were removed by fire, if only temporarily.

Reducing surface and ground fuels is a vital part of the research. Brown and Davis (1973) state: "Surface fuels include the loose surface litter on the forest floor, normally consisting of fallen leaves or needles, twigs, bark, cones, and small branches that have not yet decayed sufficiently to lose their identity." Ground fuels are those combustible materials beneath the loose surface materials including duff, roots, punky wood, etc. Most fires start and spread in the surface fuels as flaming combustion. Ground fuels are generally consumed as glowing combustion in a relatively unspectacular manner. Large woody fuels in the form of fallen trees, limbs, broken tops, etc. make up a different heat source. The rate of large fuel consumption, and the environmental conditions under which they burn, can produce very localizing effects such as torching of tree crowns and long-distance spot fire occurrence.

Live fuels can also cause spectacular fire behavior when the air is dry and the wind is strong. Fuel ladders are formed by stagnated stands of ponderosa pine (doghair thickets) that can transform a surface fire into a crowning fire that results in severe damage to the overstory. About 4 million acres of these overstocked stands are found in Arizona and New Mexico (Shubert 1974).

General Study Description

In 1976, a 20-year study was designed to determine a burning interval adequate to provide continuous fire hazard abatement. Two sites were selected for study. The Chimney Spring Unit is on volcanic-derived basalt soils, on the Fort Valley Experimental Forest near Flagstaff, Ariz. Because ponderosa pine in the Southwest grows in different soil types, a second area was selected on sedimentary, sandstone-derived soils, at the Limestone Flats Unit on the Long Valley Experimental Forest, 60 miles southeast. Twenty-one 2.5-acre plots make up each study site. Three replications at 1-, 2-, 4-, 6-, 8-, and 10-year intervals constitute the burning treatments; three plots were set aside as controls. Fuel conditions were sampled intensively because of the importance of the initial fire. Eliminating as much fuel as possible with the first fire without undue stand damage is important to longer rotation treatments. Fuel amounts 1 inch in diameter and less on the forest floor were determined by analyzing 756 1-square-foot samples (36 per plot). Fuel conditions in the larger size classes were determined by 168 sampling planes (8 per plot) using the woody fuel sampling scheme described by Brown (1974). Initial fires were set in two different years on the companion study areas.

Chimney Spring Unit

Except for some firewood cutting of old, downed snags, the Chimney Spring Unit was virtually undisturbed. It is 5.5 miles directly south of San Francisco Peaks and at an elevation of 7,400 feet. The area is tentatively classified as Brolliar stoney clay loam soil.[3] Annual precipitation at Fort Valley, 3 miles west, is about 22 inches per year (Schubert 1974); daily mean temperature ranges from 23° to 62° F.

Stand Description

Stand structure was typical of Arizona ponderosa pine—many even-aged groups of varying area sizes. Reproduction (all trees less than 4.5 feet tall) averaged 395 stems per acre; saplings (0.6 to 3.9 inches d.b.h.), 1,114 per acre; small poles (4.0 to 6.9 inches d.b.h.), 195 per acre; poles (7.0 to 10.9 inches d.b.h.), 117 per acre; and sawtimber (greater than or equal to 11.0 inches d.b.h.), 54 per acre. Basal area averaged 144 square feet per acre for all trees 4 inches d.b.h. and larger. The site index was 82.

Fuel Description

The Chimney Spring Unit had 15.17 tons per acre of dead surface and ground fuel less than or equal to 1 inch in diameter. Of that, about 3.35 tons was found in the surface fuel (L layer), composed mostly of needles (2.11 tons). About 10% (0.32 ton) was 0- to 1/4-inch woody material and 19% (0.65 ton) was 1/4- to 1-inch woody material. The remainder was bark, cone parts, and other material too small to efficiently identify.

Ground fuels (F and H layers) accounted for 78% of the material less than or equal to 1 inch in diameter (11.82 tons per acre). Ground fuel needle material accounted for 10.08 tons per acre; 0- to 1/4-inch woody material, 0.47 ton; 1/4- to 1-inch woody material, 0.66 ton; and other material made up the remainder (table 1).

Woody material 1 to 3 inches in diameter averaged 0.81 ton per acre. Sound woody material greater than 3 inches in diameter averaged 2.09 tons per acre. Rotten material in the same size class was more than double the weight of sound material, with an average of 4.26 tons per acre. Large sound material had an average diameter of 6 inches, and rotten material averaged 10.8 inches.

[3]*Meurisse, Robert T. 1971. Soils report, San Francisco Peaks area, Elden and Flagstaff Ranger Districts, Coconino National Forest. USDA Forest Service, Mimeo Report, 47 p. Division of Watershed Management, State and Private Forestry, Southwestern Region, Albuquerque, N. Mex.*

Table 1.—Dead fuel loading, prescribed burning interval study, Chimney Spring Unit, 1976

Dead fuel component	Fuel loading	Proportion of layer	Proportion of ≤1-inch material
	tons/acre	*percent*	
Surface fuel (≤1-inch diameter)			
L layer			
Needles	2.11	63	14
0- to 1/4-inch woody	0.32	10	2
1/4- to 1-inch woody	.65	19	4
Other (<1/4-inch)	.27	8	2
Total	3.35	100	22
Ground fuel (≤1-inch diameter)			
F layer			
Needles	3.88	77	26
0- to 1/4-inch woody	.29	6	2
1/4- to 1-inch woody	.43	8	3
Other (<1/4-inch)	.45	9	3
Total	5.05	100	34
H layer			
Humus	6.20	92	41
0- to 1/4-inch woody	.18	3	1
1/4- to 1-inch woody	.23	3	1
Other (<1/4-inch)	.16	2	1
Total	6.77	100	44
Ground fuel total	11.82		78
Surface and ground fuel total	15.17		100
All fuel (≤1-inch diameter)			
Needles/humus	12.19		80
0- to 1/4-inch woody	.79		5
1/4- to 1-inch woody	1.31		9
Other (<1/4-inch)	.88		6
Total	15.17		100
Large woody fuel (>1-inch diameter)			Proportion of >1-inch material
1- to 3-inch woody	.81		11
Over 3-inch sound woody	2.09		29
Over 3-inch rotten woody	4.26		60
Total	7.16		100
All dead fuel total	22.33		

Fire Description

Rainfall was below normal on the Chimney Spring plots during late summer and fall. On October 21, 1976, 0.27 inch of rain was recorded at the fire site. Four days later (October 25) 0.03 inch fell. Eleven days later, November 5, the study area was burned. Because of the generally dry conditions, burning took place at night. Ignition began at 5:30 p.m. and continued until 7:00 p.m.

Measured surface needle moisture content increased from 8% to 12% during the night. Ground fuel (F and H needles) moisture content through the evening ranged from 10% to 19%. Temperatures in the stand dropped from 59° F at 5:30 p.m. to 37° F at midnight. Relative humidity increased from 21% to 48% during the same time period. Backing fires were used for a while, but when they no longer continued to carry well, short (30 to 40 feet between strips) strip head fires were used. Rates of spread were no greater than 12 feet per minute but generally remained in a range of 4 to 6 feet per minute. Flame lengths in litter fuels seldom exceeded 16 inches.

Results

The first fire to burn through the Chimney Spring Unit since 1876 altered the fuel and stand conditions considerably. Fire consumed the surface needles on 94% of the area. Mineral soil was exposed on 16% of the area. Fuel less than or equal to 1 inch in diameter (needles, twigs, cones, etc.) were reduced from 15.17 to 5.67 tons per acre (63%). Ground fuel was reduced from an average depth of 1.7 to 0.6 inches.

Of the surface and ground fuels, needles and humus were reduced the most (8.13 tons per acre). These are the fuels (expecially L layer needles) that cause most of the dynamic behavior in a fire in these ponderosa pine forests. Eliminating needles removes the fire hazard in these dead forest fuels. As the needles continue to accumulate, the hazard reappears. Hazard reduction must be a continuing process; it cannot be accomplished by a single fire.

The greatest fuel reductions occurred around the bases of the old pines (usually greater than 18 inches d.b.h.). In most cases, the fire consumed literally all dead fuel around these trees down to mineral soil. Fuel sampling around the bases of these old pines showed fuel loadings as high as 2.34 pounds per square foot (51 tons per acre) before burning. However, the area burned to mineral soil under pole stands (4 to 11 inches d.b.h.) was generally not as large as under the old pines. In the doghair thickets, only the L layer needles and small twigs were consumed. In fact, the fires did not carry well through the thickets. Mineral soil was exposed to a very limited amount around the bases of some saplings.

Woody fuel 1 to 3 inches in diameter was reduced by 54%. Large woody fuel (greater than 3 inches in diameter) was reduced by 71%. Virtually all of the large rotten logs (91%) were totally consumed (99% weight reduction), but only about 14% of the large sound material weight was burned. The number of large sound logs remained essentially the same, indicating that the resistance to control was not completely eliminated. Loading of sound material was reduced by a reduction in the diameter of the pieces. By eliminating the rotten, punky material, however, part of the potential threat of firebrand (pieces of burning material) production and receptive ignition sites was eliminated. Where large woody fuels were totally consumed, the fine surface and ground fuels under and close to those large fuels were also consumed to mineral soil. White ash beds were common after the fire. All fuel reduction is summarized in table 2.

Limestone Flats Unit

One year after the interval burning study was begun at Chimney Spring, a companion study was established

Table 2.—Dead fuel reduction from a prescribed fire in an Arizona ponderosa pine stand, Chimney Spring Unit, 1976

Dead fuel component	Fuel loading before fire	Fuel loading after fire	Fuel reduction
	tons/acre		percent
Surface and ground fuel			
Needles/humus	12.19	4.06	67
0- to 1/4-inch woody	0.79	[1]0.27	66
1/4- to 1-inch woody	1.31	[1].99	24
Other material	.88	[1].35	60
Total	15.17	5.67	63
Large woody fuel			
1- to 3-inch woody	.81	.37	54
Over 3-inch sound woody	2.09	1.79	14
Over 3-inch rotten woody	4.26	.04	99
Total	7.16	2.20	69
All dead fuel total	22.33	7.87	65

[1]*Components based on analysis of samples from three plots.*

60 miles southeast on the Long Valley Experimental Forest. Limestone Flats is on sandstone-derived soils, with outcroppings of limestone present throughout the area. The soils are classified as McVickers very fine, sandy loam (Wheeler and Williams 1974). A light sanitation cut was made in 1967 to eliminate trees that had been or were likely to be attacked by insects or disease. Some snags were cut during the harvest. Livestock grazing had been eliminated for many years. Like most ponderosa pine forests in Arizona, this is an uneven-aged stand made up of even-aged groups. Its composition differs from Chimney Spring in that it does not have as many pole-sized (7- to 10.9-inches d.b.h.) groups.

Stand Description

Reproduction (all trees less than 4.5 feet tall) averaged 556 stems per acre; saplings (0.6 to 3.9 inches d.b.h.), 1,166 per acre; small poles (4.0 to 6.9 inches d.b.h.), 122 per acre; poles (7.0 to 10.9 inches d.b.h.), 35 per acre; and sawtimber (greater than or equal to 11.0 inches d.b.h.), 33 per acre. Basal area averaged 98 square feet per acre for all trees 4 inches d.b.h. and larger, and site index was 72.

Fuel Description

The Limestone Flats Unit had 15.71 tons per acre of dead surface and ground fuel less than or equal to 1 inch in diameter. Of that, about 2.65 tons (17%) were found in the surface fuel (L layer), 1.24 tons (8%) of which was needles. Approximately 0.16 ton was 0- to 1/4-inch woody material and 0.83 ton was in the 1/4- to 1-inch class.

Ground fuel (F and H layers) accounted for 83% of the material less than or equal to 1 inch in diameter (12.93 tons per acre). Ground fuel needle material was found to be 9.85 tons per acre (63%); 0- to 1/4-inch woody material, 0.32 ton per acre (2%); and 1/4- to 1-inch woody material, 1.28 tons per acre (8%) (table 3). Fine fuel loading was essentially the same as on Chimney Spring and proportioned similarly by layer. Surface needles were less prevalent at Limestone Flats.

Woody material 1 to 3 inches in diameter averaged 2.19 tons per acre. Sound woody material greater than 3 inches in diameter averaged 5.22 tons per acre. Rotten material in the same size class was almost twice as heavy (9.15 tons per acre). Large sound logs averaged 7.7 inches in diameter and rotten logs 8.9 inches. Woody fuel loadings at Limestone Flats were more than twice as much as Chimney Spring, probably because of prior logging activities.

Table 3.—Dead fuel loading, prescribed burning interval study, Limestone Flats Unit, 1977

Dead fuel component	Fuel loading	Proportion of layer	Proportion of ≤1-inch material
	tons/acre	percent	
Surface fuel (≤1-inch diameter)			
L layer			
Needles	1.24	47	8
0- to 1/4-inch woody	0.16	6	1
1/4- to 1-inch woody	.83	31	5
Other (<1/4-inch)	.42	16	3
Total	2.65	100	17
Ground fuel (≤1-inch diameter)			
F layer			
Needles	3.47	61	22
0- to 1/4-inch woody	.23	4	1
1/4- to 1-inch woody	.92	16	6
Other (<1/4-inch)	1.04	19	7
Total	5.66	100	36
H layer			
Humus	6.38	88	41
0- to 1/4-inch woody	.09	1	1
1/4- to 1-inch woody	.36	5	2
Other (<1/4-inch)	.44	6	3
Total	7.27	100	47
Ground fuel total	12.93		83
Surface and ground fuel total	15.58		100
All fuel (≤1-inch diameter)			
Needles/humus	11.09		71
0- to 1/4-inch woody	.48		3
1/4- to 1-inch woody	2.11		13
Other (<1/4-inch)	1.90		12
Vegetation	.13		1
Total	15.71		100
Large woody fuel (>1 inch diameter)			Proportion of >1-inch material
1- to 3-inch woody	2.19		13
Over 3-inch sound woody	5.22		32
Over 3-inch rotten woody	9.15		55
Total	16.56		100
All dead fuel total	32.14		

Fire Description

More than 10 inches of precipitation was recorded on the site from July 1 to October 26, 1977, when the area was burned. Large, sound fuels had dried out inside (18% to 44% moisture content), but regular showers during August and September left the outside of the material wet (greater than 160% moisture content). Large rotten material was soggy throughout in most cases. Surface and ground fuels during the 2 days of burning averaged 7.4%, 11.0%, and 28.1% moisture content for the L, F, and H layers, respectively. The wet H layer was another indication of the wet fall. Back fires were used for the most part, but strip head fires were necessary when backing fires would not carry. Strip head fire spread rates seldom exceeded 5 feet per minute.

Results

Despite the relatively moist burning conditions, the first fire at Limestone Flats since the turn of the century changed the fuel and stand situation considerably (fig. 1). An estimated 86% of the entire area burned. Fires did not travel well in the grass where much green material remained. The fire exposed mineral soil on about 16% of the area, mostly around large, old pines. Dead fuel loading was reduced by about 43% (table 4). High moisture content in the H layer explains most of the difference between fuel consumption at Chimney Spring and Limestone Flats. Because the large fuels were wet, much of them remained. The number of sound logs was reduced by 60%; the number of rotten logs was reduced by only 34%. This again illustrates the presence of high fuel moistures. The weight was reduced by 47% and 41%, respectively.

Table 4.—Dead fuel reduction from a prescribed fire in an Arizona ponderosa pine stand, Limestone Flats Unit, 1977

Dead fuel component	Fuel loading before fire	Fuel loading after fire	Fuel reduction
	------- *tons/acre* -----		*percent*
Surface and ground fuel			
Needles/humus	11.09	6.57	41
0- to 1/4-inch woody	0.48	0.29	40
1/4- to 1-inch woody	2.11	1.15	46
Other	1.90	1.06	44
Vegetation	.13	.07	46
Total	15.71	9.14	42
Large woody fuel			
1- to 3-inch woody	2.19	1.21	45
Over 3-inch sound woody	5.22	2.76	47
Over 3-inch rotten woody	9.15	5.37	41
Total	16.56	9.34	44
All dead fuel total	32.27	18.48	43

Potential rates of spread of surface fires was temporarily reduced by a single fire at Limestone Flats also. Surface fuels were eliminted from 86% of the area. The lack of total consumption of large fuels leaves the resistance to control still present, but not nearly as great. Rotten, punky logs remain as possible sources of firebrands as well as receptors of firebrands. Many of the sound logs that remained were charred extensively. Because the outside material was pyrolized, it will be more difficult to ignite the logs a second time.

Figure 1.—The first fire at Limestone Flats since the turn of the century changed the fuel and stand situation considerably.

Other Results

Aerial ladder fuels in the form of doghair thickets have been mentioned as a serious fire problem in ponderosa pine stands. Many stagnated trees were thinned from the stands at both sites during the first fires. Although it was a good start in reducing the overstocked stands and aerial fuels, it will take many more prescribed fires and changes in technique to make these stands more productive and more resistant to damage from wildfire.

Literature Cited

Brown, Arthur A., and Kenneth P. Davis. 1973. Forest fire: Control and use. 686 p. McGraw-Hill, Inc., New York, N.Y.

Brown, James K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report INT-16, 24 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Cooper, Charles F. 1961. Controlled burning and watershed condition in the White Mountains of Arizona. Journal of Forestry 59:438-442.

Davis, James B., Peter F. Ffolliott, and Warren P. Clary. 1968. A fire prescription for consuming ponderosa pine duff. USDA Forest Service Research Note RM-115, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Gaines, Edward M., Harry R. Kallander, and Joe A. Wagner. 1958. Controlled burning in southwestern ponderosa pine: Results from the Blue Mountain plots, Fort Apache Indian Reservation. Journal of Forestry 56:323-327.

Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA Forest Service Research Paper RM-123, 71 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Truesdell, Paul S. 1969. Postulates of the prescribed burning program of the Bureau of Indian Affairs. Proceedings of the Tall Timbers Fire Ecology Conference 9:235-240. Tallahassee, Fla.

Wheeler, L. D., Jr., and John A. Williams. 1974. Soil survey of the Long Valley Area, Arizona. USDA Forest Service and Soil Conservation Service in cooperation with Arizona Agricultural Experiment Station, 78 p. Superintendent of Documents, Washington D.C.

Plant a tree! Mark the 75th birthday of the Forest Service by giving a living gift to future generations.

Agriculture—CSU, Fort Collins

Rocky Mountains | Southwest | Great Plains

Research Note RM-393

October 1980

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

A Computer Program to Calculate the Susceptibility of Spruce-Fir Stands to Spruce Beetle Outbreaks

J. A. Logan,[1] J. M. Schmid,[2] and M. S. Mehl[3]

CLEMSON UNIVERSITY LIBRARY
APR 21 1981
SCI., TECH. & AGR DIV.

The computer program shows spruce beetle hazard ratings directly from data collected for stage II timber inventories.

Keywords: *Abies lasiocarpa, Dendroctonus rufipennis, Picea engelmannii,* computer programs

Schmid and Frye (1976) presented a plan for rating the susceptibility of Engelmann spruce-subalpine fir (*Picea engelmannii* Parry and *Abies lasiocarpa* (Nutt.) Hooker) stands to spruce beetle (*Dendroctonus rufipennis* (Kirby)) infestation. The plan ranks the susceptibility of the stand based on its physiographic location, basal area, average diameter of the spruce, and percentage of spruce in the overstory.

During the past 5 years, inventory projects in the Rocky Mountain Region of the USDA Forest Service have been gathering intensive data on spruce-fir stands by the methods outlined in the 1980 edition of the Region's "Silvicultural Examination and Prescription Handbook" (FSH 2409.260). Substantial information is gathered for each stand, some of which is used in the Schmid-Frye system. The data are recorded on field forms and eventually are transferred to magnetic tapes which are stored in the project's headquarters.

Since its origin, the rating system has received limited use in the southern and central Rockies. To increase its usefulness to forest managers, a computer program was written to calculate stand susceptibility from the inventory data. The program reads the inventory file for the stand, extracts the essential information, computes the stand rating, and prints it out, identifying the stand by the location data commonly recorded.

This program may give a slightly different rating for each stand from stage II inventory data than it would if the data were gathered in the same manner as was used to develop the rating system. In Schmid and Frye (1976), the limits for each category in the basal area, diameter, and percent spruce characteristics were based on data derived from fixed radius plots. Stage II data are derived from variable radius plots and different basal area factors. How this will affect the stand rating is not known at this time, but no significant change is assumed.

The program is compatible with USDA Forest Service, Rocky Mountain Region program processing data collected from the stage II inventory. The program could be integrated into the master program of the Region to run as a subroutine so that the stand rating for spruce beetles would be automatically included in the printout with the other stand information regularly presented. There is also the possibility of a computer-produced, differentially shaded or colored, overlay map representing a mosaic of standing ratings for the different stands in the spruce-fir forest. If the Schmid-Frye rating system is adopted with modifications for regional conditions in other western regions of the USDA Forest Service, this program can also be easily modified for use with it.

[1]*Assistant Professor, Zoology and Entomology, Colorado State University.*

[2]*Entomologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is at Fort Collins, in cooperation with Colorado State University.*

[3]*Forester, Timber Inventory, Rocky Mountain Region, USDA Forest Service, Fort Collins, Colo.*

Literature Cited

Alexander, Robert R. 1967. Site indexes for Engelmann spruce. USDA Forest Service Research Paper RM-32, 7 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Schmid, J. M., and R. H. Frye. 1976. Stand ratings for spruce beetles. USDA Forest Service Research Note RM-309, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Appendix I

Once data for a specific stand has been isolated from the data file for all the stands using an add command in the Univac 1100 text editing routine from the Univac Manual UP-8723, program processing requires no additional input. The inventory file for the stand is searched by the program for information required for computation of stand spruce beetle susceptibility index. The program calls USDA Forest Service subroutine ESSITE for computation of site index based on Alexander (1967). On output, the program lists:

1. Alexander's site index
2. Total number of trees processed
3. Number of sample trees with d.b.h. greater than 2.6 inches
4. Number of sample spruce with d.b.h. greater than 10.0 inches
5. Stand risk rating from Schmid and Frye (1976)

Schmid/Frye Value	Program Output
4-5	Low
6	Low Medium
7-9	Medium
10	Medium High
11-12	High
See example problem	

Appendix II

Program listing

```
C       ----PROGRAM TO ESTIMATE SUSCEPTIBILITY OF A SPRUCE STAND TO
C       ----SPRUCE BEETLE ATTACK
C
C       ----DATA INPUT IS STANDARD REGION-2 STAGE I/II STAND DATA
C       ----IT IS ASSUMED THAT DATA IS FOR SPRUCE STANDS ONLY
C       ----AS MANY SPRUCE STANDS AS NECESSARY CAN BE INPUTED AT ONE TIME
C*******----USE UNIT 7 FOR DATA INPUT
      DIMENSION X(4),IASCI(2,5),ASI(20),ITITL(12)
      DATA IASCI/4HHIGH,1H ,4HMED ,4HHIGH,4HMEDI,2HUM,4HLOW ,3HMED,
     13HLOW,1H /
C ...
C ... TDBH = TOTAL LIVE DBH .GT. 2.6 IN
C ... TSDBH = TOTAL LIVE SPRUCE .GT. 2.6 IN
C ... TC = TOTAL DBH IN CANOPY .GT. 2.6 IN
C ... TSC = TOTAL SPRUCE IN CANOPY .GT. 2.6 IN
C ... SDBH10 = TOTAL SPRUCE .GT. IN REGARDLESS OF POSITION
C ... XBAI IS BASIAL AREA INDEX
C ... XHI = TREE HEIGHT
C ... NUM=NUMBER OF ADDITIONAL STEMS
C ... XAGE = TREE AGE
C ...
C ...
C ... ICNT = COUNTER FOR TOTAL TREES PROCESSED
C ... ICNT2 = COUNTER FFR TREES OVER 2.6 IN. DBH
C ... ICNT3 = COUNTER FFR SPRUCE OVER 10. DBH
C ... NPLTS = COUNTER FOR NUMBER OF PLOTS
C ... IPLTS1 = SECOND PLOT COUNTER
C ... ISITC = COUNTER FOR SITE TREES
C ...
```

```
C ... RSK = SITE INDEX
      TDBH=0.
      TSDBH=0.
      TC=0.
      TSC=0.
      SDBH10=0.
      IUNIT=7
C
C ... READ HEADER CARD
  197 CONTINUE
      NPLTS=0
      IPLTS1=0
      ICNT=0
      ICNT2=0
      ICNT3=0
      ISITC=0
      IEND=0
      READ(IUNIT,198,END=98) IDX1,IDX2,(ITITL(I),I=1,12)
  198 FORMAT(2I6,1X,11A6,A1)
      IUNIT=7
C ... DUMMY READ LOOP TO GET AT DATA
   20 READ(IUNIT,199,END=98) ICT,IASCI2,IASCI1
C     WRITE(6,199)ICT,IASCI2,IASCI1
  199 FORMAT(12X,I1,16X,A2,8X,A1)
      IF(ICT.NE.2)GO TO 21
      DECODE(1,501,IASCI1)IRSK
  501 FORMAT(I1)
C ...
C ... XBAI IS BASAL AREA INDEX FROM INPUT
  555 FORMAT(10X,"IRSK,XBAI",I5,10X,1PE14.7)
C ...
      DECODE(2,502,IASCI2)XBAI
C     WRITE(6,555)IRSK,XBAI
  502 FORMAT(F2.0)
      GO TO 20
   21 CONTINUE
      IF(ICT.NE.8)GO TO 20
C ... READ DATA CARDS
    1 READ(IUNIT,101,END=98,ERR=99)ISIT1,ISIT2,ICT,IPLTS,ITH,ITSP,DBH,
     1XHI,NUM,XAGE,ITPOS
  101 FORMAT(2I6,I1,I3,7X,I2,I3,F3.1,F3.0,I2,5X,F3.0,10X,I1)
C      ----CHECK FOR NEW STAND
      IF(ICT.EQ.1) GO TO 505
C ... ISIT = SITE ID
C ... ICT= CARD TYPE
C ... ITH = TREE HISTORY -- "01" IS LIVE TREE -- "99" IS SITE TREE
C ... ITSP = TREE SPECIES
C ... DBH = DBH
C ... IRSK = PHYSIOLOGICAL LOCATION "IRSK=8 .THEN. HIGH RISK
C ...
C ... BRANCH TO READ IF NOT LIVE TREE
      IF(IPLTS.NE.IPLTS1)NPLTS=NPLTS+1
      IPLTS1=IPLTS
C ... CHECK FOR SITE TREE
      IF(ITH.EQ.1)GO TO 2
      IF(ITH.NE.99)GO TO 1
C ...
C ... TREE IS SITE TREE
C ... ASSUME TREE IS SPRUCE
C ... FROM FOREST SERVICE SUBROUTINE
      ISITC=ISITC+1
      CALL ESSITE(XHI,XAGE,ASI(ISITC))
      GO TO 1
    2 CONTINUE
      NUM=NUM - 1
      IF(NUM.LT.0) NUM=0
      ICNT=ICNT + 1 + NUM
      NUM=0
C ... DISREGARD TREE IF LESS THAN 2.6 IN.
      IF(DBH.LT.2.6)GO TO 1
      ICNT2=ICNT2+1
      DDDH=(DBH/2.)/12.
      DDH=DDDH*DDDH*3.2425962
C     WRITE(6,500)DBH,DDDH
  500 FORMAT(10X,2(1PE14.7))
      TDBH=TDBH+DDDH
      IF(ITSP.GT.90)TSC=TSC+DDDH
    6 IF(DBH.LT.10.)GO TO 1
```

```
      IF(ITSP.LT.90)GO TO 1
      ICNT3=ICNT3+1
      SDBH10=SDBH10+DBH
      GO TO 1
   98 IEND=1
      GO TO 505
   99 CONTINUE
C      ----CHECK FOR ERROR IN DATA FORMAT
      IF(ICT.EQ.1) GO TO 505
      WRITE(6,504) ISIT1,ISIT2
  504 FORMAT(" THERE HAS BEEN AN ERROR IN READING THE DATA FOR"
     1" STAND  ",2I6,/,"    RUN TERMINATED")
      STOP
  505 CONTINUE
      IF(IPLTS1.EQ.NPLTS)GO TO 7
C     WRITE(6,503)NPLTS
  503  FORMAT(10X,"ERROR -- PLOT NUMBER AND COUNT NOT EQUAL",
     1/,10X,"NUMBER OF PLOTS COMPUTED AS = ",I4)
    7 CONTINUE
C ... COMPUTE AVERAGE DIAMETER OF LIVE SPRUCE ABOVE 10. IN. DBH
C ... -- ALL LIVE SPRUCE TREES USED, BOTH CANOPY AND UNDERSTORY
      IF(ICNT3.GT.0)GO TO 10
      WRITE(6,300)
  300  FORMAT(10X,"STAND CONTAINS ZERO SPRUCE ABOVE 10. IN. DBH",/
     1,10X,"VARIABLE X(2) SET TO ZERO")
      X(2)=0.
      GO TO 19
   10 X1=FLOAT(ICNT3)
C ... * * NOTE XBAI IS BASAL AREA INDEX * *
      X(2)=SDBH10/X1
   19 CONTINUE
C ... COMPUTE TOTAL STAND DBH REGARDLESS OF SPECIES OR TREE POSITION
C ... TREES MUST BE GREATER THAN 2.6 DBH TO BE INCLUDED
      X1=ICNT2
      X2=NPLTS
      X(3)=(X1/X2)*XBAI
C ... COMPUTE PERCENT SPRUCE IN CANOPY - TREES .GT. 2.6 DBH ONLY
      X(4)=100.*(TSC/TDBH)
C ... CONVERT RAW VALUES TO RISK VALUES
C     WRITE(6,900)X(1),X(2),X(3),X(4)
  900  FORMAT(10X,4(1PE14.7))
C ... SITE INDEX
      IF(ISITC.LE.0)GO TO 600
C     WRITE(6,*)"ISITC = ",ISITC
      X1=ISITC
      RSK=0.
      DO 40 I=1,ISITC
C     WRITE(6,*)"ASI(",I,") = ",ASI(I)
      RSK=RSK+ASI(I)
   40 CONTINUE
      RSK=RSK/X1
      X(1)=2.
      IF(RSK.LT.80.)X(1)=1.
C ... CHECK FOR CREEK BOTTOM OR DRAW
      IF(IRSK.EQ.8)X(1)=3.
C ... BEGIN OUTPUT
      WRITE(6,603)(ITITL(I),I=1,12)
  603  FORMAT(//,10X,"SPRUCE BEETLE STAND RATING FOR ",11A6,A1)
      WRITE(6,601)RSK
  601  FORMAT(10X,"ALEXANDERS SITE INDEX = ",F10.4)
      X1=X(2)
      X(2)=3.
      IF(X1.LT.16.)X(2)=2.
      IF(X1.LT.12.)X(2)=1.
      X1=X(3)
      X(3)=3.
      IF(X1.LT.150.)X(3)=2.
      IF(X1.LT.100.)X(3)=1.
      X1=X(4)
      X(4)=3.
      IF(X1.LT.65.)X(4)=2.
      IF(X1.LT.50.)X(4)=1.
C ... COMPUTE RISK SCORE
      XRSK=0.
      DO 30 I=1,4
      XRSK=XRSK+X(I)
   30 CONTINUE
      IOUT=1
```

```
      IF(XRSK.LT.11.)IOUT=2
      IF(SRSK.LT.10.)IOUT=3
      IF(XRSK.LT.7.)IOUT=4
      IF(XRSK.LT.6.)IOUT=5
      WRITE(6,301)ICNT,ICNT2,ICNT3,(IASCI(I,IOUT),I=1,2)
  301 FORMAT(10X,//,
     110X,"TOTAL TREES PROCESSED IN STAND = ",I3,
     2/10X,"TREES PROCESSED WITH DBH %2.6 IN. = ",I3,/
     310X,"TREES PROCESSED WITH DBH%10.0 IN. = ",I3,///
     410X,"STAND RISK RATING FOR SPRUCE BEETLE IS ",2A4,//)
C       ----CHECK TO SEE IF END OF DATA
      IF(IEND.NE.0) STOP
C       ----REREAD TITLE CARD FOR NEW STAND AND BEGIN PROCESSING NEW STAND
      IUNIT=30
      GO TO 197
  600 CONTINUE
      WRITE(6,602)
  602 FORMAT(10X,"NO SITE TREES -- PROGRAM ABORT")
      STOP
      END
      SUBROUTINE ESSITE(HT,AGE,SITE)
C SUBROUTINE TO COMPUTE SITE INDEX FOR ENGELMANN SPRUCE-REFERENCE
C ALEXANDER 1967 RESEARCH PAPER RM-32 TABLE 1.
C INPUT TREE HEIGHT (HT) AND BREAST HEIGHT AGE(AGE). OUTPUT SITE INDEX
C (SITE).
      DIMENSION HTSI(30,10), HROW(10), AG(30), SI(10)
      DATA HTSI/30*0.,4.5,6.,11.,15.,20.,24.,29.,33.,37.,40.,43.,46.,48.
     1,51.,53.,55.,56.,58.,59.,60.,61.,62.,2*63.,6*64.,4.5,9.,16.,22.,28
     2.,33.,38.,42.,46.,50.,53.,56.,59.,61.,64.,66.,67.,69.,70.,71.,72.,
     373.,2*74.,6*75.,4.5,13.,22.,29.,36.,42.,47.,52.,56.,60.,64.,67.,70
     4.,72.,74.,76.,78.,80.,81.,82.,83.,84.,2*85.,6*86.,4.5,16.,27.,36.,
     544.,50.,56.,61.,66.,70.,74.,77.,80.,83.,85.,87.,89.,90.,92.,93.,94
     6.,2*95.,2*96.,5*97.,4.5,20.,33.,43.,52.,59.,65.,70.,75.,80.,84.,88
     7.,91.,94.,96.,98.,100.,101.,103.,104.,105.,2*106.,2*107.,5*108.,4.
     85,23.,39.,50.,59.,67.,74.,80.,85.,90.,94.,98.,101.,104.,107.,109.,
     9111.,112.,114.,115.,116.,2*117.,3*118.,4*119.,4.5,27.,44.,57.,67.,
     176.,83.,89.,95.,100.,105.,109.,112.,115.,118.,120.,122.,123.,125.,
     2126.,2*127.,128.,3*129.,4*130.,4.5,30.,50.,64.,75.,84.,92.,98.,104
     3.,110.,115.,119.,123.,126.,129.,131.,133.,134.,135.,136.,137.,138.
     4,139.,3*140.,4*141.,4.5,34.,55.,71.,83.,93.,101.,108.,114.,120.,12
     55.,130.,133.,136.,139.,142.,144.,145.,146.,147.,148.,149.,2*150.,2
     6*151.,4*152./
      DATA AG/0.,20.,30.,40.,50.,60.,70.,80.,90.,100.,110.,120.,130.,140
     1.,150.,160.,170.,180.,190.,200.,210.,220.,230.,240.,250.,260.,270.
     2,280.,290.,300./
      DATA SI/0.,40.,50.,60.,70.,80.,90.,100.,110.,120./
      DATA HROW(1)/0./
      TEM=AGE
      IF(TEM.GT.300.)TEM=300.
      DO 10 I=2,30
      I1=I-1
      I2=I
      IF(AG(I)-TEM) 10,20,20
   10 CONTINUE
   20 DO 30 J=2,11
      J1=J-1
      J2=J
      HROW(J)=(HTSI(I1,J)*(TEM-AG(I2))-HTSI(I2,J)*(TEM-AG(I1)))/(AG(I1)-
     1AG(I2))
      IF(HROW(J)-HT) 30,40,40
   30 CONTINUE
   40 IF(HROW(J)-HT) 50,60,60
   50 SITE=120.
      RETURN
   60 SITE=(SI(J1)*(HT-HROW(J2))-SI(J2)*(HT-HROW(J1)))/(HROW(J1)-HROW(J
     1))
      RETURN
      END

 TAJAPKL      5 PAGES PRINTED.
?>#JOB.SEPARATOR#<?
```

Appendix III

Example Run

A. Data
B. Program Execution
C. Output

```
@DATA,L SPRUCEDATA.
DATA 9R1 SL74T9 08/15/80 09:23:57 (1)
    1.      1037070016121386  WILLIAMS CREEK
    2.      1037070016122020 94206797 00530300  01032 01X  GA0111
    3.      1037070016124080550311111010000000002       01
    4.      1037070016126F16C008G13774230020362102550680W06       115
    5.      1037070016128  0016
    6.      103707001612900101      01093077025      18039  008200  1
    7.      103707001612900102      01093128041      09156  018255  1
    8.      103707001612900103      01093070028             009200  1
    9.      10370700161290 1        0109304001501            8
   10.      103707001612900104      01093000000  008  029    0  00  2
   11.      103707001612900105      01093000001             0  00  2
   12.      103707001612900106      01093000004             0  00  2
   13.      103707001612900201      01093159058      08168  019227  1
   14.      103707001612900202      01093182057      06224  019227  1
   15.      103707001612900203      01093058028      05090  008355  2
   16.      103707001612900204      01093144055      06220  009227  1
   17.      103707001612900205      01093140045             029227  1
   18.      103707001612900206      01093080033             019300  2
   19.      103707001612900207      01093027013  02804051    09300  2
   20.      103707001612900208      01093040019  02809065    09300  2
   21.      103707001612900209      01093033016             09300  2
   22.      103707001612900210      01093000003             0  00  2
   23.      103707001612900301      06093161024                    3
   24.      103707001612900302      01102118025              8     2
   25.      103707001612900303      01102178027              8     2
   26.      103707001612900304      06102116021                    3
   27.      103707001612900305      01093071027             009300  1
   28.      103707001612900306      01093056024             008300  2
   29.      103707001612900307      01093197046      05189  248252  1
   30.      103707001612900308      01093186048             148252  1
   31.      103707001612900309      01093065028             019255  1
   32.      103707001612900310      01093025012              08472  2
   33.      103707001612900311      01093028012              07451  2
   34.      103707001612900312      01093026009              07451  2
   35.      103707001612900313      01093015008              07451  2
   36.      103707001612900314      01093010007              07451  2
   37.      103707001612900401      01093090024             487228  2
   38.      103707001612900402      01093131028             029255  1
   39.      103707001612900402      99093131028        068   9255      2
   40.      103707001612900501      01093117034             008200  2
   41.      103707001612900502      01093071030             017255  2
   42.      103707001612900503      01093228075      06200  007255  1
   43.      103707001612900504      01093094033             008200  2
   44.      103707001612900505      01093013007              08400  2
   45.      103707001612900506      01093000001              0  00  2
   46.      103707001612900507      01093000000              0  00  2
   47.      103707001612900508      01093000000              0  00  2
   48.      103707001612900501      99093117034        048   8200      2
```

```
   49.      103707001612900503      99093228075       200     7255      2
END DATA. ERRORS: NONE. TIME:  0.723 SEC. IMAGE COUNT: 49

@FIN


      @RUN,J/S R2TMRR,1102602411   ,INVADP,1,75/2000

      @ASG,A SPRUCEDATA.

      @ASG,A SPRUCEBEETLE.

      @USE  7, SPRUCEDATA.

      @XQT SPRUCEBEETLE.XQT

                SPRUCE BEETLE STAND RATING FOR 386  WILLIAMS CREEK
                ALEXANDERS SITE INDEX =    50.9557


                TOTAL TREES PROCESSED IN STAND =  39
                TREES PROCESSED WITH DBH >2.6 IN. =  28
                TREES PROCESSED WITH DBH>10.0 IN. =  12


                STAND RISK RATING FOR SPRUCE BEETLE IS MEDIUM



      @FIN
```

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-394

March 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Cydia youngana (Kearfott) (Lepidoptera:Tortricidae) and Associates in Engelmann Spruce Cones, Fraser Experimental Forest, Colorado 1974-1977

J. M. Schmid, James C. Mitchell, and Robert E. Stevens[1]

UNIVERSITY LIBRARY
JUN 26 1981
SCI., TECH. & AGRIC.

Insect-caused seed loss in Engelmann spruce (*Picea engelmannii* Parry) varied from 13% to 33% between 1974 and 1977. The primary seed-eating insects were a spruce seedworm, *Cydia* (=*Laspeyresia*) *youngana* (Kearfott), and an unidentified species of fly, possibly a *Hylemya*, found only in the larval stage. Twenty other species were found associated with the cones. In 1975 the flight period of *C. youngana*, determined from light trap catches, peaked around June 28. About 45% of each *C. youngana* generation adults did not emerge until at least the second year after completing their development. An undescribed species of *Elfia*, a tachinid, parasitized *C. youngana*. Because damaged cones cannot be differentiated from sound cones, seed collectors should consider the amount of potential damage when determining their needs.

Keywords: Seed and cone insects, *Cydia youngana*, *Picea engelmannii*.

Management Implications

Because damaged cones cannot be differentiated from ound cones and the average seed loss per cone can be igh, seed collection projects should determine the average eed loss per cone for each collection site and adjust their eeds accordingly.

Introduction

Abundant seed crops do not occur annually in Engelann spruce, *Picea engelmannii* Parry, in the central ocky Mountains (Alexander 1969, Ronco and Noble 971). Small crops can be attributed to a variety of factors, including insect-caused damage to cone and seed production. In white spruce, *Picea glauca* (Moench) Voss, Tripp, and Hedlin (1956) discovered that little or no sound seed was produced in years of small cone crops because the few cones produced were heavily infested by insects. In white spruce in Alaska, insect damage was also greatest when few cones were produced (Werner 1964). Even during good seed years, the percentage of sound seed may be only 25% to 40% of the total seed collected (Alexander and Noble 1976).

The initial goal of this study was to measure the impact of insects on Engelmann spruce seed production at the Fraser Experimental Forest, 70 km west of Denver, Colo., and to identify the responsible insect species. When it was determined in 1974 that *Cydia* (=*Laspeyresia*) *youngana* (Kearfott) was the principal seed destroyer, added studies were undertaken during the period 1975-1978 to determine

[1] *Entomologist, Forest Research Technician, and Entomologist, spectively. Rocky Mountain Forest and Range Experiment Station, headquarters in Fort Collins, in cooperation with Colorado ate University.*

the peak flight period of *C. youngana* and the number of diapausing larvae.

Methods

One conebearing tree was selected outside of, but adjacent to, each corner of 10 previously-established seed collection plots[2] in the Fraser Experimental Forest. Plots ranged in elevation from 2,780 to 3,517 m, and were on differing aspects. Study trees ranged from 20 to 32 m in height.

To determine cone and seed damage by insects, five cones were to have been removed from each tree at weekly intervals from August to the end of seed drop each year from 1974 to 1977, for a total of 20 cones per plot per week. However, only the 1975 and 1977 cone crops permitted this quantity of sampling. During the other years, five or fewer cones were taken weekly at each plot, depending on cone availability. Conebearing branches were shot off trees with a .22 caliber rifle, labeled, and brought to the laboratory for examination. The total number of sound and damaged seeds within the productive zone of the cone (after Tripp, 1954), insect species, developmental stages, and distribution within the cone, were recorded for each collection. Because the maximum amount of damage was evident in the September samples, they were used to determine the mean number of infested cones, damaged seeds, etc. A 2-way analysis of variance was used to test for differences in seed damage attributable to elevation and aspect.

During 1975, one fluorescent and one blacklight trap were installed in the middle crown of an Engelmann spruce tree, about 20 m above the ground (fig. 1) to discover the peak flight period of *C. youngana*, the most important seed destroyer. Adults were trapped during eight 3-day periods, beginning on June 7 and then intermittently until July 26.

More than 400 cones were collected each February from 1976 through 1979 to determine the numbers of *C. youngana* remaining in diapause within the cones. The cones were brought to the laboratory and isolated individually in vials to determine emergence. After 60 days at room temperature (22° C), emerged insects were counted and the cones dissected. All live *C. youngana* larvae found during dissections were counted as diapausing.

Voucher specimens of insects reported on are kept either at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., or in the U.S. National Museum, Washington, D.C.

Results and Discussion

Impact on Seed Production

Twenty-two different species of insects were found associated with Engelmann spruce cones during the study peri-

[2]*Alexander, Robert R. 1968. Seed production of Engelmann spruce in uncut stands in relation to seed source. Study Plan 1201.24, on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., 33 p.*

Figure 1.—Light trap position in Engelmann spruce.

od (table 1). Two of these were seed eaters; the rest were parasites, predators, or scale, fungus, or foliage feeders.

A seed moth, *Cydia youngana* (Kearfott), was responsible for most of the insect-caused seed loss, accounting for an average annual loss of 28% of the total seed production (table 2). The annual loss was 32% or 33% during the first 3 years but decreased to 14% the last year. Within infested cones, an average of 39% of the seeds was damaged during the 4 years.

Seed loss to *C. youngana* accounts for a large portion of unsound seed at the Fraser Experimental Forest. During the years of this study (1974-1977) seed caught in traps at Fraser averaged 56% unsound (Alexander and Noble 1976; Alexander, personal communication). Thus the 28% seed loss caused by *C. youngana* in this study may account for 50% of all the unsound seed.

The seed moth infested an average of 68% of the cones during the 4 years. The percentage of infested cones was highest in 1976 when cone production was lowest (table 2). Simultaneously, the mean percent of cones infested with two or more larvae was also highest. This indicates that moth may oviposit more eggs on fewer cones in poor cone years and thus cause a higher percentage to have multiple infestations.

There were no significant differences in damage attributable to elevation or aspect.

Flight, Oviposition, and Feeding Habits of *Cydia youngana*

The life history and habits of *C. youngana* were similar to those reported from British Columbia by Tripp (1954)

Table 1.—Insects associated with Engelmann spruce cones

Insect	Habits	Years found	Percent of cones colonized
Lepidoptera			
Tortricidae			
Cydia youngana (Kearfott)	Seed eater	1974-77	70
Diptera			
Tipulidae			
Tipula sp.	Plant feeder	1974	<1
Sciaridae			
Bradysia sp.	Fungus feeder	1974-77	<2
Cecidomyiidae			
Dasineura sp.	Scale feeder	1974-76	48
Tachinidae			
Elfia n. sp.	Parasite	1974-77	5
Unidentified larva[1]	Seed eater	1976	15
Hymenoptera			
Ichneumonidae			
Dolichomitus sp.	Parasite	1976	([2])
Porizon moderator (L.)	Parasite	1976	([2])
Exeristes comstockii Cr.	Parasite	1976	([2])
Scambus longicorpus Wly.	Parasite	1976	([2])
Scambus protentus Wly.	Parasite	1976	([2])
Scambus hispae Harris	Parasite	1976	([2])
Braconidae			
Bracon sp.	Parasite	1974-77	3
Torymidae			
Torymus sp.	Parasite	1974-77	3
Pteromalidae			
Mesopolobus sp.	Parasite	1976	9
Unidentified species A	Parasite	1976	5
Unidentified species B	Parasite	1976	2
Platygastridae			
Platygaster sp.	Parasite	1974-77	14
Coleoptera			
Lathridiidae			
Melanophthalma sp.	Fungus-mold feeder	1976	<1
Corticaria sp.	Fungus-mold feeder	1976	<1
Hemiptera			
Anthocoridae			
Tetrapheps canadensis Prov.		1976	<1
Thysanoptera			
Thripidae			
Oxthrips sp.	Plant feeder	1974-77	30

[1] *Possibly Hylemya sp.*
[2] *Ichneumonidae as a group colonized 2.5% of the cones in 1976.*

In 1975, adult moths flew from early June to late July with peak flight in the latter part of June (fig. 2). Of the two light sources used, blacklight attracted the most moths. Eggs were deposited from early June until early July in all 4 years of the study. Most eggs were deposited on the apical half of the cone.

After hatching, *C. youngana* larvae moved to the center or productive zone of the cone (fig. 3) where most feeding took place. Feeding within the cone (fig. 4) continued until September when the larvae hibernated. In 1976, when most cones were infested, two or more *Cydia* larvae often became established within the rachis of a single cone. In such cases the larvae separated themselves with plugs of frass (fig. 5). Although cannibalism was not directly observed, it was occasionally evident during cone dissections.

Despite the feeding of *Cydia* larvae within a cone, the cone shows no outward sign of damage, and cone collectors cannot readily distinguish between heavily damaged cones and relatively sound cones. However, damage is easily seen when cones are dissected, and persons obtaining cones for seed collection purposes should dissect a sample of cones to determine the quality of the seed.

The average number of larvae in each cone, and the number of multiple larvae per cone varied over the study period. Larvae were found in the greatest numbers in 1975, when 19 larvae were observed in one cone, and 5 to 7 per

cone was common. The maximum number of larvae completing development in a single cone was three. Between 35% and 55% of the *C. youngana* larvae diapaused each year (table 3), indicating a substantial portion of the population has at least a 2-year life cycle.

Unidentified Dipterous Seed Eater

Unidentified fly larvae infested 15% of the cone samples in 1976 (table 1), accounting for 41% of the destroyed seed. They were not present in 1974, 1975, or 1977. The larvae were observed eating seeds within the cone from early June until late July, when they presumably left the cones. These habits suggest the larvae were a species of *Hylemya* (Muscidae). Hedlin (1973) reported *Hylemya anthracina* (Cz.), a spiral spruce cone borer with similar characteristics and capabilities, in Engelmann spruce cones in British Columbia.

Other Insects

Of the other insects listed in table 1, *Platygaster* sp. (Hymenoptera: Platygastridae) was rare in 1974 and 1975, but infested 14.2% of the cones in 1976 (514 cones, 73 insects). Species of *Platygaster* are reportedly parasitic on *Cecidomyiidae* (Borror and White 1970); the increased population of platygastrids in 1976 may have been responsible for a decrease in midge populations we observed that year.

Table 2.—Cone infestation statistics for *Cydia youngana* for 10 plots, Fraser Experimental Forest

	Year cones were infested				
	1974	1975	1976	1977	Mean
Number of cones examined	60	620	45	400	
Mean percent of infested cones	72	67	92	41	68
Mean percent of total seeds damaged	32	32	33	14	28
Mean percent of damaged seeds in only infested cones	37	46	35	38	39
Mean percent of cones with 2 or more larvae	25	27	62	6	30

Table 3.—Numbers of dead, matured, and diapausing *Cydia youngana* larvae

	Year cones were infested			
	1975	1976	1977	1978
Cones collected	434	414	442	490
Larvae dead	49	45	9	163
Matured larvae (Emerged as adult)	180	122	31	82
Live larvae (Diapausing)	111	103	18	98
Larvae in diapause (percent)	38	46	37	54

Elfia n. sp. (Diptera:Tachinidae) was common all years (e.g., 1976 rearings of 514 cones produced 28 insects, or an infestation rate of 5.4%). The larvae are parasitic on *C. youngana* (fig. 6). The parasite was noted only after the host larva had moved to the cone rachis.

Acknowledgements

The authors wish to express their gratitude to Jon L. Herring, John M. Kingsolver, Paul M. Marsh, Robert W. Carlson, George W. Byers, Raymond J. Gagne, Curtis W. Sabrosky, Donald R. Davis, Kellie O'Neill, B. D. Burks, Gordon Gordh, U.S. National Museum; Henry K. Townes, American Entomological Institute; and Fred G. Andrews, California Department of Agriculture for insect identifications.

Literature Cited

Alexander, Robert R. 1969. Seedfall and establishment of Engelmann spruce in clearcut openings: A case history. USDA Forest Service Research Paper RM-53, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Alexander, Robert R., and Daniel L. Noble. 1976. Production of Engelmann spruce seed, Fraser Experimental Forest, Colorado: A 5-year report. USDA Forest Service Research Note RM-324, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Borrer, Donald J., and Richard E. White. 1970. A field guide to the insects of North America north of Mexico. 404 p. The Peterson Field Guide Series. Houghton-Mifflin Co., Boston, Mass.

Hedlin, A. F. 1973. Spruce cone insects in British Columbia and their control. Canadian Entomologist 105(1):113-122.

Ronco, F., and D. L. Noble. 1971. Engelmann spruce regeneration in clearcut openings not insured by record seed crop. Journal of Forestry 69:578-579.

Tripp, H. A. 1954. Descriptions and habits of the spruce seedworm (*Laspeyresia youngana* (Kft.) (Lepidoptera: Olethreutidae). Canadian Entomologist 86(9):385-402.

Tripp, H. A., and A. F. Hedlin. 1956. An ecological study and damage appraisal of white spruce cone insects. Forestry Chronicle 32(4):400-410.

Werner, R. A. 1964. White spruce seed loss caused by insects in interior Alaska. Canadian Entomologist 96(11):1462-1464.

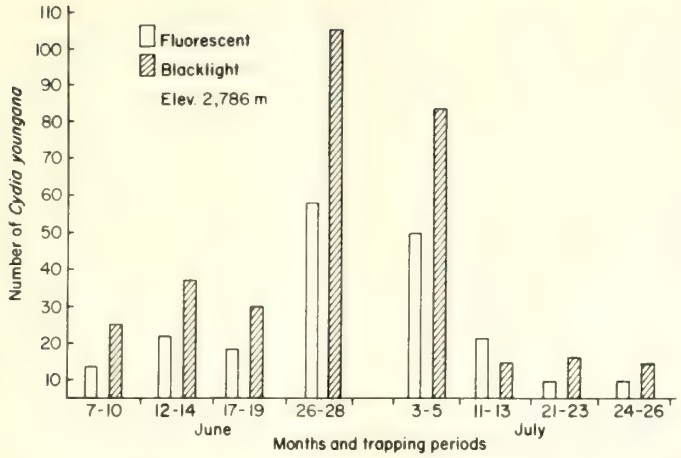


Figure 2.—Flight period of *Cydia youngana* determined by light trapping, Fraser Experimental Forest, Colorado, 1975.

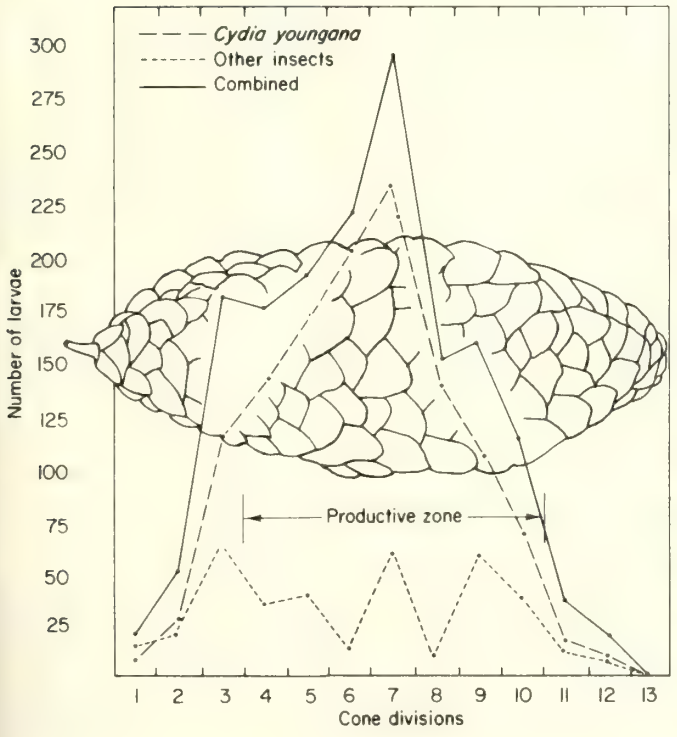


Figure 3.—Distribution of larvae within Engelmann spruce *Picea engelmannii* Parry cones on the Fraser Experimental Forest, 1974.

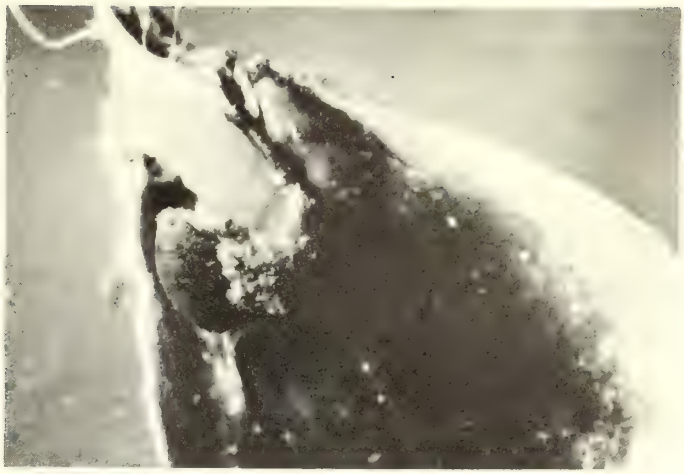


Figure 4.—Seed destruction by *Cydia youngana* larva.

Figure 5.—*Cydia youngana* larvae in rachis of Engelmann spruce cone. Larvae are separated by a plug of frass.

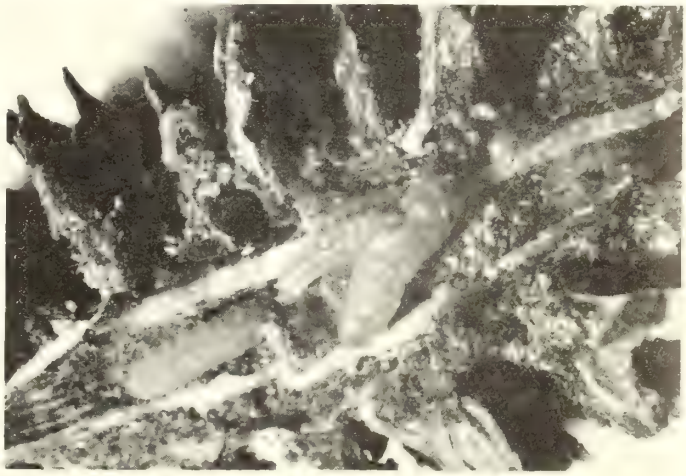


Figure 6.—Parasitism of *Cydia youngana* larva by *Elfia* n. sp.

Rocky
Mountains

Southwest

Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-395

March 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Characteristics of Scaled Quail Loafing Coverts in Northwest Texas[1]

CLEMSON UNIVERSITY LIBRARY
JUN 26 1981
SCI., TECH. & AGR. DIV.

Fred A. Stormer[2]

Cholla cactus (*Opuntia imbricata*) provided cover in 85% of scaled quail (*Callipepla squamata*) loafing coverts during winter and spring. All coverts had a band of lateral cover within the canopy of the overhead shrub. Two to five paths through the lateral cover led to a central, vegetation-free area.

Keywords: *Callipepla squamata*, *Opuntia imbricata*, *Salsola kali*, wildlife habitat.

Management Implications

Active scaled quail loafing coverts should be protected from brush control measures to ensure continued year-round quail use of large treated areas. Existing shrubs, under which vegetation has been grazed short, may make attractive loafing coverts by placing brush around approximately 70% of their periphery and eliminating herbaceous vegetation underneath the central area of the canopy. Planting scattered clumps of cholla could benefit scaled quail on areas devoid of suitable winter loafing coverts. As an alternative, artificial loafing coverts can be designed to include overhead cover, lateral cover, and a central, vegetation-free area.

[1]*Acknowledgment is made to Jay Taylor, owner of the Rafter O Ranch, who provided the study area for this research. The cooperation of Lee Roy McCracken, Rafter O Ranch Manager, is greatly appreciated. John Graves, District Conservationist, Soil Conservation Service, was helpful in the location of the study area and providing maps that were essential for the conduct of this research.*

[2]*Research Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is in Fort Collins in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Lubbock, in cooperation with Texas Tech University.*

Introduction

A loafing covert is a unit of cover used for daytime resting and protection. In Colorado, scaled quail (*Callipepla squamata*) winter use of areas depends on suitable loafing coverts (Snyder 1967). Because cover protects animals from predators and weather conditions (Thomas 1979), survival is related to the quality of loafing coverts. Compared to most other southwestern quail species, scaled quail population levels during drought seem to depend more on survival than on reduced breeding success (Brown 1978, Brown et al. 1978).

This note describes the floristic and structural features of loafing coverts in northwest Texas.

Study Area and Methods

The study was conducted in Oldham County, about 35 miles (56 km) east of the New Mexico-Texas border, along the southern escarpment of the Canadian River. The area is characterized by steep canyons that break out onto a relatively gently sloping broad plain to the north. There are a large variety of woody species associations. Woody species include yucca (*Yucca angustifolia*), sandsage (*Artemisia filifolia*), honey mesquite (*Prosopis*

glandulosa), fragrant sumac (*Rhus aromatica*), mountain-mahogany (*Cercocarpus montanus*), cholla cactus (*Opuntia imbricata*), and one-seeded juniper (*Juniperus monosperma*).

Data were collected from mid-January to early May, 1980. In the Texas Panhandle, this period is characterized by a reduction in cover that is frequently aggravated by cattle grazing and periodic drought. Snow, low temperatures, and high winds during winter increase scaled quail's need for protective cover.

Data were collected on 73 loafing coverts. Coverts were found by locating radio-tagged birds and by searching the various vegetation types in a 1,500-acre (607-ha) area. A unit of cover was considered a loafing covert if it had an accumulation of quail fecal droppings under overhead woody cover and one or more well-worn paths into the cover. There is also an accumulation of fecal droppings at night roosts, but observation of radio-tagged birds showed that they roost in spots without overhead cover. In several cases, coverts were located when birds flushed from under them.

Vegetation types with coverts were characterized by their woody species, without regard to order of dominance. However, at each covert location, note was made of the woody species that was dominant in horizontal coverage. Woody species that made up the overhead cover and surrounding lateral screening cover of each covert were recorded. Lateral cover was further delineated by the presence of dead Russian thistle (*Salsola kali*), standing grass, and forbs, and estimates of the percentage of the periphery of the covert surrounded by lateral cover. The number and directional orientation of well-used openings or paths through the lateral cover also were noted. Beginning in February, the diameter and height of the overhead cover were recorded. Type of substrate (bare ground and litter) under the overhead cover was recorded at 39 coverts examined in March and April. These data may or may not be representative of all coverts examined between mid January and early May. Confidence intervals for means are given at the 95% level of probability.

Results and Discussion

Coverts were found in 11 vegetation types. More tha 75% were in yucca, yucca-cholla, mesquite-yucca-cholla and mesquite-yucca-cholla-sandsage associations (table 1) The mesquite-yucca-cholla and mesquite-yucca-cholla sandsage associations accounted for nearly half of the loca tions. Yucca was present in 96%, mesquite in 56%, an cholla in 79% of the associations.

In a concurrent study, observations of radio-tagge birds during the winter and spring confirm high use o vegetation with cholla present. In New Mexico and Col orado, there also is a close association of scaled quail wit cholla (Campbell 1952, Hoffman 1965). In addition, th geographic distribution of Arizona scaled quail (*C. s pallida*) (Aldrich and Duvall 1955), or *C. s. pallida* and *C s. hargravei* as defined by Rea (1973), closely parallels tha of cholla (Benson 1969, Weniger 1969, Frazer and Piepe 1972).

All coverts examined had the following four commo features: (1) overhead woody cover; (2) lateral screenin cover; (3) a central area with bare soil and no herbaceou vegetation; and (4) one or more paths through the latera cover into the center of the covert.

Overhead Cover

Height of 41 coverts varied from 1.6 to 5.9 feet (0.5 t 1.8 m); diameters of 39 coverts ranged from 2.6 to 6.9 fe (0.8 to 2.1 m). The mean height was 4.6 ± 1.0 feet (1.4 ± 0.3 m), and the average diameter was 3.9 ± 0.3 feet (1.2 ± 0.1 m).

Cholla formed all or part of the overhead cover of 85% of the coverts (table 1, fig. 1); yet, it was the dominar woody species at only 12 (16%) of the locations. Selectio for cholla seemed apparent where it was a less abundar associate of mesquite and yucca. Cholla formed all or pa of the overhead cover of 25 of 27 coverts at locatior where mesquite was the dominant woody species, and

Table 1.—Types of overhead cover and vegetation associations for scaled quail loafing coverts found during January-May 1980

Vegetation association [1]	Overhead cover											
	M, Rt	M,C, Rt	M	Man-made	DC,Rt	C, S	Fs	C, M	C, Rt	C	Total	Percent
M Y C	1		1					4	4	9	19	26.0
M Y C S			1					4	3	9	17	23.3
Y C						2	1		2	8	13	17.8
Y				1	3		1	1	1	1	8	11.0
Y S C						2				2	4	5.5
Y M		1							1	1	3	4.1
Y S				2			1				3	4.1
M C										2	2	2.7
Y Fs Mm C							2				2	2.7
Y J Mm C										1	1	1.4
G					1						1	1.4
Total	1	1	2	3	4	4	5	9	11	33	73	
Percent	1.4	1.4	2.7	4.1	5.5	5.5	6.8	12.3	15.1	45.2		100.0

[1] *C = cholla cactus; DC = dead cholla cactus; Fs = fragrant sumac; G = grass; J = one-seeded juniper; M = honey mesquite; Mm = mountain-mahogany; Rt = Russian thistle blown into the covert; S = sandsage; Y = yucca.*

21 or 23 coverts at locations where yucca dominated the woody cover.

In the grass and yucca vegetation types (table 1), most of the cholla and mesquite had been eliminated by brush control measures, in which case quail made use of dead and scattered live cholla for coverts. Artificial structures also provided overhead cover in areas having little or no cholla present.

Mesquite formed all or part of the overhead cover of 13 coverts but only in 3 cases without an associated cholla. Fragrant sumac was used also, even at locations where cholla was present in the woody plant association (table 1). In Oklahoma, Schemnitz (1961) reported that cholla, fragrant sumac, and artificial structures were used as covey resting areas during winter.

Good populations of scaled quail occur in many ranges devoid of cholla. In these cases, other woody species assume importance in providing overhead cover for resting coverts. Wolfberry (*Lycium* spp.) and mesquite (*P. juliflora*) were used for loafing cover in Arizona (Goodwin and Hungerford 1977), and mesquite clumps were used as loafing sites in southeastern New Mexico (Banks 1970). Other woody cover also may be important where the growth form of existing cholla does not provide necessary structural features for resting coverts.

Lateral Cover

The presence of lateral screening cover seemed essential for use of a site. Shrubs without lateral cover were not used (fig. 2). Lateral cover consisted of a band of relatively tall vegetation lying largely within the peripheral canopy of the overhead cover (fig. 1). This area usually is protected from grazing by the low branches of the central shrub. The percentage of the peripheries of the coverts screened varied from 30% to 100%, with an average of 70% ± 4%. In 13 coverts examined in February, the minimum heights of the lateral cover varied from 0.7 to 2 feet (0.2 to 0.6 m). Maximum heights ranged from 1 to 3 feet (0.3 to 0.9 m).

Figure 1. — Loafing covert used by scaled quail during January showing overhead cholla cover and lateral cover of grass and Russian thistle.

Figure 2. — Cholla without lateral cover of grass and Russian thistle in the periphery of the crown. High-crowned shrubs without lateral cover were not used by scaled quail for resting coverts from January to early May.

Two or more different kinds of cover usually provided the lateral screening. Russian thistle that had been blown into the coverts most frequently was the form of cover, but grass also was important (table 2). These two types of cover occurred together in 64% of the coverts. With the exception of Russian thistle, forbs were not important. In some cases, primarily with cholla and yucca, the canopy of the overhead cover and/or adjacent shrubs formed part of the lateral screen.

Table 2. — Types of lateral cover found in scaled quail loafing coverts during January-May 1980

Lateral cover	Number of coverts	Percent of coverts
Russian thistle	66	90.4
Grass	53	72.6
Yucca	20	27.4
Cholla cactus	13	17.8
Honey mesquite	7	9.6
Forbs	4	5.5
Fragrant sumac	4	5.5
Mountain-mahogany	1	1.4

Other Features

Although an area of bare soil was characteristic of the centers of all of the coverts, about 13% of them had an accumulation of litter. It is not known whether the absence of vegetation and exposure of soil in the center of the covert is a prerequisite for occupancy by scaled quail.

All coverts had 1 to 5 paths or openings through the lateral cover into the center area. The number of openings were distributed as follows:

Number of Openings	Frequency	Percent
1	2	2.7
2	32	43.8
3	33	45.2
4	4	5.5
5	2	2.7

A chi-square test indicated a significant departure ($P<0.01$) in the directional orientation of the openings from that expected if their orientations were uniformally distributed among the eight principal points of the compass. They tended to be oriented toward the north, northeast, and east (fig. 3). Fewer than the expected number were oriented toward the southeast, southwest, west, and northwest.

Significance to Survival

The overhead and lateral cover in coverts, especially the spiny cover of cholla, prevents access by avian predators, either through the canopy or from the side. Lateral cover may not protect scaled quail from mammalian predators, but more than one opening in the lateral cover would facilitate escape.

By blocking cold wind, the lateral cover helps to maintain thermal balance. However, protection is usually less on the northwest quadrant of the coverts, where most of the openings tended to be oriented (fig. 3). The openings seem to be oriented in the direction of less lateral cover. Probably because of the direction of prevailing winds, Russian thistle tended to accumulate in the other three quadrants, which, in turn, protected grass within this portion of the covert from grazing. The net effect was that the densest cover tended to be in the northwest, southwest, and southeast quadrants of the coverts.

By allowing sunlight to penetrate to ground level, the open crown of cholla and the absence of herbaceous cover in the center of the covert helps maintain thermal balance during cool weather. Also, sunlight and the absence of litter help dry the substrate quickly.

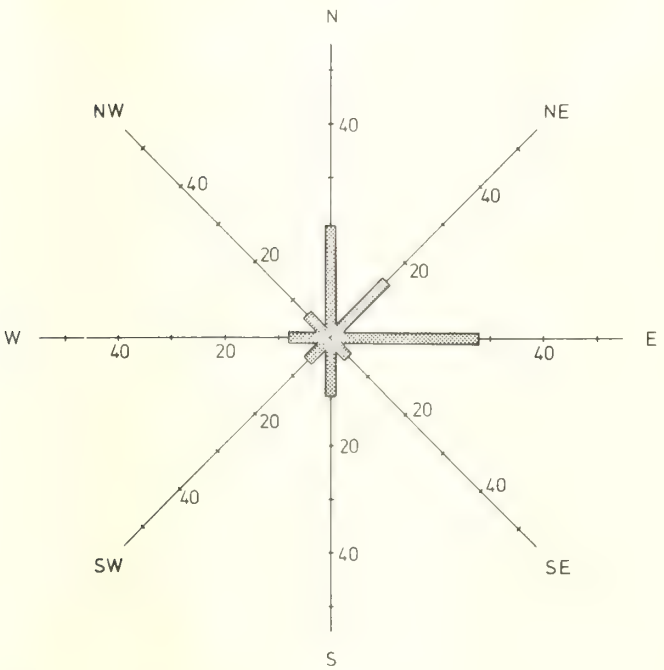


Figure 3. — Percentage distribution in the directional orientation of openings of scaled quail loafing coverts.

Conclusions

All coverts examined, regardless of species, had common structural features. Any species of overhead cover, which lends itself to formation of those features, may produce adequate resting coverts for scaled quail during the winter and early spring.

Protection of Existing Cover

Current research is assessing the number of coverts in covey winter home ranges. However, based on Schemnitz's (1961) estimate of winter home range size, one loafing covert per 52-70 acres (21-28 ha) would seem minimal for scaled quail to use an area.

When brush control is carried out, active coverts or potential coverts should be reserved to maintain quail use of the range. Active coverts can be identified during the winter by the accumulation of droppings. Individual plants and clumps of woody cover that could potentially serve as coverts will have branches sufficiently close to the ground to protect grass within the periphery of the crown from grazing. The low crown of fragrant sumac nearly always provides lateral cover.

Although no woody species should be discounted, cholla should be given strong consideration when protecting loafing coverts. Individual-plant treatment by grubbing, removal with a fork lift, or by spraying with herbicides are effective methods of cholla control (Scifres 1980). In this case, individual cholla coverts can be easily spared. Broadcast, aerial application of herbicides for brush control would require reserving motts or strips of cover rather than individual shrubs.

Burning of rangelands may not eliminate cholla over an extended period of time (Bunting et al. 1980). Also, quail used dead cholla (table 1). However, fire may cause necrosis of the lower branches, which could prevent formation of adequate lateral cover in the presence of grazing.[3]

Although scaled quail are more tolerant of grazing than other upland game birds (Snyder 1967), heavy livestock use would reduce lateral cover around coverts—the two most important components of which were Russian thistle and grass. Russian thistle rates as a fair livestock forage in early spring, before the spines harden (USDA Forest Service 1937). Excessive grazing or drought would preclude its development. Although, under normal circumstances, the overhead crown protects grass that forms the lateral cover, its density and height would be progressively reduced under continued heavy grazing. Cambell et al. (1973) noted that scaled quail do best on moderately-grazed ranges. Nevertheless, utilization of as little as 20% to 40% of the forage could be highly detrimental to grassland birds during drought periods (Brown 1978). The effects of a reduction in lateral cover by grazing could be partially mitigated by an interspersion of small fenced areas containing loafing coverts. However, this may not be economically practical. As an alternative, coverts could be protected with brush.

[3]*Personal conversation with Henry A. Wright, Department of Range and Wildlife Management, Texas Tech University, Lubbock, 1980.*

Cover Development

Scaled quail readily respond to placement of cover on ranges deficient in adequate coverts (Schemnitz 1961, Snyder 1967, Snyder 1970). Information from this study can be used as a guide for cover development.

Existing shrubs greater than 1.6 feet (0.5 m) in height and 2.6 feet (0.8 m) in diameter, under which the vegetation has been grazed short, may be made attractive by placing limbs around 75% of the periphery of the canopy. If present, Russian thistle will accumulate in the matrix of limbs. The brush should be of sufficient height and density to provide protection from grazing, and yet, permit growth of grass to 1 to 1.6 feet (0.3 to 0.5 m). Bare ground should be exposed in the center by removing herbaceous vegetation and any accumulation of litter. Although the herbaceous vegetation may eventually grow back, quail use of the covert should impede its development.

In some low-crowned shrubs, a dense, tall growth of herbaceous vegetation forms underneath the entire crown. This cover may be made attractive by removing the herbaceous vegetation from the center and from about 20% to 30% of the periphery. Herbaceous vegetation could be removed by hand hoeing in fall or by application of a grass-selective herbicide during the growing season. However, Rea and Pieper (n. d.) reported that spraying around the base with a grass-selective herbicide was detrimental to cholla.

Various tree and shrub species have been transplanted for scaled quail cover in New Mexico (Campbell 1952) and Colorado (Snyder 1967). Highest survival was attained with cholla. In Colorado, 100% survival was attained with specimens 0.5 to 1 foot (0.15 to 0.3 m) high. Cholla transplants up to 2.5 feet (0.76 m) tall with only remnants of their roots and planted into dry ground had excellent survival, although they received no moisture for a month after transplanting (Snyder 1967). Because branch growth of cholla 1.6 feet (0.5 m) tall is only about 2.4 to 3.1 inches (60 to 80 mm) per year (Frazer and Pieper 1972), planting small cholla in groups might produce attractive overhead cover in a shorter period of time.

Establishing plantings of overhead cover inside fenced livestock exclosures, as has been done in both New Mexico (Campbell 1952) and Colorado (Snyder 1967), would ensure development of essential lateral cover. However, dense herbaceous growth inside an exclosure can impede scaled quail access (Snyder 1970). An alternative would be to place limbs around the periphery of the plantings to protect grass from grazing.

Erection of artificial loafing coverts is a recommended management practice (Campbell 1952, Schemnitz 1961, Snyder 1967, Snyder 1970). Although explicit design is not essential (Snyder 1970), the structure of the cover should be similar to that of naturally occurring coverts (i.e., the design should provide for overhead cover, lateral cover around approximately 70% of the periphery, a central area free of vegetation, and two and five openings in the lateral cover to allow access and escape). Placing limbs or poles around a standing post or dead tree or over a wooden frame (Snyder 1970) could provide these features. The overhead cover should not be so dense as to prevent penetration of sunlight to the ground. Some loose brush around the perimeter would allow growth of lateral cover. Soil sterilents should be used in the center area of brush shelters to prevent growth of herbaceous vegetation (Snyder 1967).

Based on measurements made in this study, an artificial structure need not cover more than 10.8 to 14 square feet (1 to 1.3 m^2), although larger structures would not preclude quail use and may be needed where large numbers of birds are present, as at feeders. No measurements were made of the central, vegetation-free area of coverts. However, head room of about 1 foot (0.3 m) probably would be adequate for an artificial shelter.

Literature Cited

Aldrich, John W., and Allen J. Duvall. 1955. Distribution of American gallinaceous game birds. U.S. Department of the Interior Circular 34, 23 p. Washington, D.C.

Banks, Roger L. 1970. An ecological study of scaled quail in southeastern New Mexico. M.S. thesis, 63 p. New Mexico State University, Las Cruces.

Benson, Lyman. 1969. The cacti of Arizona. 218 p. The University of Arizona Press, Tucson.

Brown, David E. 1978. Grazing, grassland cover, and gamebirds. North American Wildlife and Natural Resource Conference Transactions 43:477-485.

Brown, David E., Collins L. Cochran, and Thomas E. Waddell. 1978. Using call-counts to predict hunting success for scaled quail. Journal of Wildlife Management 42(2):281-287.

Bunting, Stephen C., Henry A. Wright, and Leon F. Neuenschwander. 1980. Long-term effects of fire on cactus in southern mixed prairie of Texas. Journal of Range Management 33(2):85-88.

Campbell, Howard. 1952. Habitat improvement for upland game birds in New Mexico. Proceedings of the annual conference of Western Association of State Game and Fish Commissioners 32:115-118.

Campbell, Howard, Donald K. Martin, Paul E. Ferkovich, and Bruce K. Harris. 1973. Effects of hunting and some other environmental factors on scaled quail in New Mexico. Wildlife Monograph 34, 49 p. The Wildlife Society, Washington, D.C.

Frazer, Joseph G., and Rex D. Pieper. 1972. Growth characteristics of *Opuntia imbricata* [Haw.]. DC. in New Mexico. The Southwestern Naturalist 17(3):229-237.

Goodwin, Jr., John G., and C. Roger Hungerford. 1977. Habitat used by native gambel's and scaled quail and released masked bobwhite quail in southern Arizona. USDA Forest Service Research Paper RM-197, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Hoffman, Donald M. 1965. The scaled quail in Colorado: Range, population status, harvest. Colorado Game, Fish and Parks Department, Technical Publication 18, 47 p. Denver.

Rea, Amadeo M. 1973. The scaled quail (*Callipepla squamata*) of the southwest: Systematic and historical consideration. Condor 75(3):322-329.

Rea, Kenneth H., and Rex D. Pieper. [n.d.] Interference between cholla cactus (*Opuntia imbricata* [Haw.] DC.) and herbaceous range vegetation. Agricultural Experiment Station Research Report 244, 7 p. New Mexico State University, Las Cruces.

Schemnitz, Sanford D. 1961. Ecology of the scaled quail in the Oklahoma Panhandle. Wildlife Monograph 8, 47 p. The Wildlife Society, Washington, D.C.

Scifres, Charles J. 1980. Brush management: Principles and practices for Texas and the Southwest. 360 p. Texas A&M University Press, College Station.

Snyder, Warren D. 1967. Experimental habitat improvement for scaled quail. Colorado Game, Fish and Parks Department, Technical Publication 19, 65 p. Denver.

Snyder, William D. 1970. Guidelines for improving scaled quail habitat. Colorado Department of Natural Resources, Division of Game, Fish and Parks, Game Information Leaflet 78, 3 p. Denver.

Thomas, Jack W., technical editor. 1979. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. U.S. Department of Agriculture, Agricultural Handbook 553, 512 p. Washington, D.C.

Weniger, Del. 1969. Cacti of the Southwest: Texas, New Mexico, Oklahoma, Arkansas, and Louisiana. 249 p. University of Texas Press, Austin.

U.S. Department of Agriculture, Forest Service. 1937. Range plant handbook. U.S. Department of Agriculture, Forest Service, Washington, D.C. [unnumbered publication]. [Reprinted 1966 and distributed by U.S. Department of Commerce, Clearinghouse for Federal Scientific and Technical Information.]

Agriculture—CSU, Fort Collins

Rocky Mountains | Southwest | Great Plains

Research Note RM-396

March 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Effects of Mountain Home Developments on Surface Water Quality: A Case Study

by
Howard L. Gary,[1] Stanley L. Ponce,[2] and Jim D. Dedrick[3]

Four mountain home developments, located adjacent to perennial streams, did not consistently increase orthophosphate, chloride, indicator bacteria, or suspended solids above existing levels of upstream contamination.

Keywords: water quality, mountain homes, Colorado Front Range, septic systems, streamflow

Management Implications

During a 2-year period, there was little statistical evidence that four specific mountain home developments in the northern Colorado Front Range increased fecal contamination, organic, or inorganic pollution of streams. High background levels of contaminants upstream apparently prevented detection of additional amounts of these pollutants. High background levels of upstream contamination are associated with potential and subtle bacterial and probable nitrate pollution of groundwater, the major source of domestic water. The relatively high levels of upstream pollution point to a great need for small community wastewater treatment plants and better home sewage treatment systems. Septic systems near live stream channels should be phased out, because they provide minimal biological treatment. Aerobic systems with disinfection, along with chemical toilets and sealed storage vaults, should be considered as substitutes.

[1]*Principal Hydrologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*
[2]*Associate Professor, Department of Earth Resources, Colorado State University, Fort Collins, Colo.*
[3]*Hydrologist, USDA Forest Service, Siskiyou National Forest, Powers Ranger District, Powers, Oreg. This note summarizes an M.S. thesis completed at Colorado State University by Dederick.*
Research supported by USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. through the Eisenhower Consortium for Western Environmental Forestry Research, Research Agreement 16-659-GR(EC-188).

Introduction

The east slope of the Colorado Rockies has become increasingly popular for residential and second-home developments. The mountain home developments vary considerably in design, and many are near streams and lakes.

Past work suggests light residential and second-home developments can degrade water quality in mountainous areas. Water quality problems stem mainly from homesite development (cutting, filling, leveling, etc.), road systems, and sewage disposal (Worms and Brickler 1967, Vice et al. 1968, Millon 1970; Howe 1972; U.S. Environmental Protection Agency 1973, Brickler and Utter 1975, Johnson and Middlebrooks 1975, Aukerman and Springer 1976, Segal 1976, Zimmerman 1979, and Ponce and Gary 1979), not from recreational uses.

Although considerable information exists on the effect of forestry and livestock practices on water quality and the environment (Montgomery 1976, Rowe and Merryman 1977), the impact of mountain home development on the quality of surface water draining the Front Range has not been fully explored.

Study Area and Home Developments

The study area is near Estes Park, Colo. (fig. 1). Average annual precipitation ranges from 40 to 65 cm. Summer thunderstorms account for more than half of the

annual precipitation. Winter precipitation is mostly snow, and normally persists until May at the higher elevations.

The area is underlain by a variety of metamorphic and granitic rocks which have weathered to weakly developed, coarse textured, and highly permeable soils. Valley bottoms contain finer textured and less permeable alluvial soils. Overstory vegetation is comprised primarily of ponderosa pine (*Pinus ponderosa* Laws), intermingled with quaking aspen (*Populus tremuloides* Michx.), Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco), blue spruce (*Picea pungens* Engelm.), and Engelmann spruce (*Picea engelmannii* Parry). Willow (*Salix* spp.), alder (*Alnus* spp.), birch (*Betula* spp.), and chokeberry (*Prunus* spp.) are the dominant woody understory plants along stream channels.

Four home developments were selected for study based on volume of streamflow, number of homes per kilometer of stream distance, and method of sewage treatment. Sampling sites were located above and below housing areas in each development.

Home developments designated areas 1 and 2 are in the community of Raymond, Colo., on the middle fork of the St. Vrain Creek, at elevations of about 2,380 m. Area 1 is between sites 1 and 2 (fig. 1), and contains about 1.3 km of stream reach. This development has high streamflow (mean discharge 2.27 m^3 per second) and high housing density—67 houses on both sides of the stream (52 homes per km of stream)—and conventional septic systems (fig. 2).

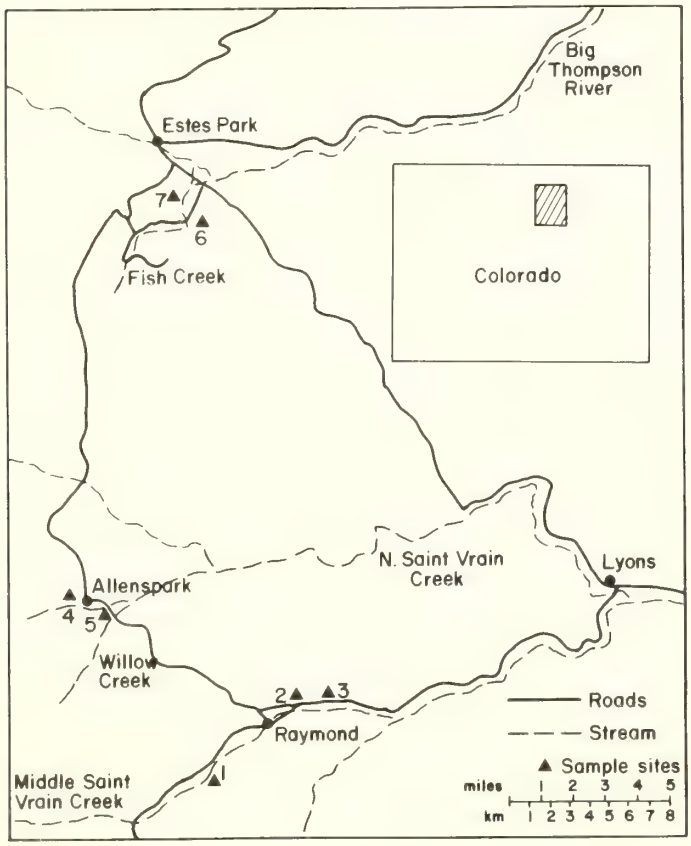


Figure 1.—Location of home areas. Numbers show sampling sites.

Area 2 is adjacent to and downstream from area 1, and is bounded by sampling sites 2 and 3 (fig. 1). Stream reach is 3.6 km, and stream discharge was the same as area 1. This area has moderate density housing—about 122 homes on both sides of the stream (34 homes per km of stream)—and mainly septic systems (fig. 2).

Most homes in areas 1 and 2 are more than 30 years old, about 35% are occupied all year, and most are within 50 m of the stream. Access to the areas is by paved highway located within 2 to 4 m of the stream. Streambanks in both areas are tree-lined, lined with large rocks, and generally stable. The water supply for most homes comes from either drilled or hand-dug wells, but most residents haul drinking water because of concern about water quality.

Area 3 is in the community of Allenspark, at about 2,600 m elevation, along a 1.4-km stretch of Willow Creek, and bounded by sample sites 4 and 5 (fig. 1). This area has low streamflow (mean discharge 0.06 m^3 per second), high density housing—77 homes on either side of the stream (55 homes per km of stream)—, and mostly septic systems (fig. 2). Most houses are within 50 m of the stream channel, more than 30 years old, and have mainly gravel access roads and driveways. Streambanks are tree-lined and stable. Water supply comes mainly from wells.

Area 4 is on a 1-km section of Fish Creek, near Estes Park, at about 2,285 m elevation, and bounded by sites 6 and 7 (fig. 1). Streamflow is low (mean discharge 0.06 m^3 per second), housing density moderate on either side of the stream (32 homes per km of stream), and is served by a gravity flow sewage collection system leading to a secondary municipal treatment plant (fig. 2). Most homes are less than 10 years old, within 100 m of the stream, and have access by paved road. Domestic water is mainly provided by a water district. Streambanks are mainly vegetated by shrubs and grass, and are relatively stable. Surface runoff from summer rains occurred occasionally from several lots.

Methods and Materials

Physical, Chemical and Biological Analysis

Stream discharge (Q) was determined by a velocity-area method using a direct reading current velocity meter. From these data, a discharge-height rating curve was developed for each site and used to estimate stream discharge during summer storms.

Suspended solids (SS) were determined by filtering and gravimetric procedures outlined in Standard Methods (American Public Health Association 1971).

Chloride (Cl) was determined using the Argentometric Method (American Public Health Association 1971).

Orthophosphate (PO_4) concentrations were determined by the ascorbic acid method (American Public Health Association 1971), and as modified by Hach (Hach Chemical Co. 1975).

Nitrate-nitrogen (NO_3-N) determinations were suspect and subsequently were discarded, because most test

SS concentrations, although statistically different in 977, were so low that any impact on the aquatic cosystem was discounted. Significantly higher PO_4 concentrations suggested possible nutrient loading from septic systems through the study reach. In addition, FS indicator bacteria counts also suggested increased contamination, probably caused by sewage effluent in area 1.

In area 2, with high streamflow, moderate housing density and septic systems, no significant increases in any of the water quality parameters monitored during either year were indicated. In general, concentrations were about the same during both years, with exception of FS counts which tripled at both upstream and downstream sampling sites during 1978. The same increases also occurred upstream in area 1 and appeared to indicate that bacterial contributions were mainly from upstream sources.

In area 3, with low streamflow, high housing density, and septic systems, Cl was significantly different ($P = .06$) during 1977 and PO_4 ($P = 0.01$) during 1978. The mean differences, while small, may indicate subtle pollution from home developments. The concentrations of both constituents were similar to those of areas 1 and 2, while the associated concentrations of FS and FC did not suggest a direct impact by home development.

In area 4, with low flow, moderate housing density, and sewage piped off-site to a wastewater treatment plant, SS ($P = 0.07$), Cl ($P = 0.01$) and FS ($P = 0.06$) were significantly different during 1977, and SS ($P = 0.01$) again during 1978. Significant differences in SS values, while relatively low, probably were related to soil disturbance associated with the more recent home development. Soil disturbed by site development was readily available for transport to the stream. Significant increases in FS apparently were influenced by home pets and local livestock, because the development did not use septic systems.

Storm Sampling

The low rainfall amounts during the five observed storms did not result in noticeable surface runoff. A comparison of mean values for routine sampling and storm sampling is summarized in table 2. A 6-hour frontal storm on August 3, 1978 was monitored at areas 1 and 2. Stream discharge before and during the storm was as follows:

	Discharge (m^3/sec)	
	Before storm	Maximum during storm
area 1	3.115	3.285
area 2	3.200	3.370

Stream discharge increased only slightly during the storm and change in SS was minor. The high background concentrations of bacteria did not further increase in home areas 1 and 2.

Two convective storms were sampled at area 3 — a 30-minute storm on July 17, and a 20-minute storm on August 25, 1978. Stream discharge during the storms was as follows:

	Discharge (m^3/sec)	
	Before storm	Maximum during storm
July 17, 1978	0.034	0.057
August 25, 1978	0.023	0.037

Streamflow increased about 66% (0.023 m^3 per second) during the first storm and 63% (0.014 m^3 per second)

Table 2.—Mean comparison of suspended solids (milligrams per liter), and fecal coliform and fecal streptococci (colonies per 100 milliliters), for routine versus storm sampling during five storms.

		Routine Sampling						Storm Sampling					
		1977			1978								
Area		SS	FC	FS	SS	FC	FS	SS	FC	FS	SS	FC	FS
								August 3, 1978					
1	U[1]	3.7	26	170	5.3	36	472	6.8	126	873	--	--	--
	D[2]	4.3	27	139	5.4	26	632	6.9	103	902	--	--	--
2	U	4.3	27	139	5.4	26	632	6.9	103	902	--	--	--
	D	4.1	26	122	5.8	35	531	7.3	77	863	--	--	--
								July 17, 1978			August 25, 1978		
3	U	4.8	8	21	6.9	4	107	8.1	79	2,433	7.1	28	910
	D	4.2	14	29	7.2	13	182	8.3	132	2,500	7.4	32	1,193
								July 29, 1978			August 26, 1978		
4	U	10.0	125	129	15.2	102	826	18.3	346	5,720	16.7	178	7,160
	D	12.2	188	185	16.4	120	733	19.6	240	5,980	18.1	252	7,240

[1]*Upstream sampling site.*
[2]*Downstream sampling site.*

during the second storm. However, analysis of water quality data collected six and four times during the first and second storms, respectively, did not indicate significant changes in SS, FC, and FS (table 2).

Two convective storms also were sampled at area 4 in 1978 (table 2). Discharge increased from about 0.007 to 0.21 m^3 per second during one storm in July and from 0.004 to 0.008 m^3 per second for a storm in August. Each storm was sampled five times. SS concentrations were relatively low, but were significantly higher downstream during both storms. FC and FS densities were greatly elevated, apparently in response to the bank wetting (Ponce and Gary 1979), but bacteria counts between upstream and downstream sites were not significantly different.

Conclusions

Measurements taken during a 2-year period and during selected summer storms indicated that paired relationships between upstream and downstream sites, in housing areas at Raymond, Allenspark, and near Estes Park, Colo. generally were not sensitive to specific impacts on stream water quality. Events of major summer storms and perodic flooding were not observed, and it is not known if such storms would indicate similar results. High background levels of upstream water contaminants known to exist (Zimmerman 1979) probably masked any subtle impacts of sewage effluents at Raymond and Allenspark. The high background levels of upstream bacterial pollution under present development and use pose minor human health hazards, as long as raw stream water is not used as potable water within any of the home developments. Under present development and use, there is little evidence of upstream organic loading within the four study areas that will significantly affect downstream use of water.

Literature Cited

American Public Health Association, Inc. 1971. Standard methods for the analysis of water and wastewater. 13th edition. 874 p. American Public Health Association, Inc., Washington, D.C.

Aukerman, Robert, and William T. Springer. 1976. Effects of recreation on water quality in wildlands. Eisenhower Consortium Bulletin 2, 25 p. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Brickler, Stanley K., and Jack G. Utter. 1975. Impact of recreation use and development on water quality in Arizona: An overview. p. 195-201. *In* Man, leisure, and wildlands: A complex interaction. Proceedings of the First Eisenhower Consortium Research Symposium. [Vail, Colo., September 14-19, 1975], Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Hach Chemical Company. 1975. Hach water and wastewater analysis procedures manual. p. 2-77, 2-78. Hach Chemical Company, Loveland, Colo.

Howe, Charles W., chairman. 1972. Residential development in the mountains of Colorado: A handbook of problems and guidelines. 106 p. United Banks of Colorado, Inc., Denver, Colo.

Johnson, B. A., and E. J. Middlebrooks. 1975. Water quality as an approach to managing recreational use and development on a mountain watershed. South Fork of the Ogden River-Ogden Valley area. PRWA 12-1. 84 p. Utah Water Research Laboratory, College of Engineering, Utah State University, Logan.

McKee, Jack Edward, and Harold W. Wolf, editors. 1963. Water quality criteria. California State Water Resources Control Board, Publication 3-A (revised). 548 p. Sacramento.

Million, Eric R. 1970. Water pollution, Red Feather Lakes area, M.S. thesis, 69 p. Colorado State University, Fort Collins.

Montgomery, James M. 1976. Forest harvest, residue treatment, reforestation and protection of water quality. 273 p. EPA-910/9-76-020. U.S. Environmental Protection Agency Region X. Seattle, Wash.

Ponce, Stanley L., and Howard L. Gary. 1979. The effect of lake based recreation and second home use on surface water quality in the Manitou Experimental Forest. USDA Forest Service Research Paper RM-211, 10 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Rowe, M. L., and Linda Merryman. 1977. Livestock and the environment—A bibliography with abstracts. Environmental Protection Technology Series. Vol. 4. 569 p. EPA-600/2-77-092. U.S. Environmental Protection Agency. Office of Research and Development. Ada, Okla.

Segall, Burton A. 1976. The impact of vacation homes on national forest water resources. Eisenhower Consortium Bulletin 3, 19 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

U.S. Environmental Protection Agency. 1973. Processes, procedures and methods to control pollution resulting from all construction activity. EPA-430/9-73/007. U.S. Environmental Protection Agency, Office of Air and Water Programs, Washington, D.C.

U.S. Environmental Protection Agency. 1975. Interim primary drinking water standards. Federal Register. Volume 40, No. 51. p. 11990-11998. Friday, March 14, 1975. Washington, D.C.

U.S. Environmental Protection Agency. 1976. Water quality and source monitoring: Field and laboratory procedure training manual. EPA-430/1-76-010. U.S. Environmental Protection Agency, Office of Water Program Operations, Cincinnati, Ohio.

Vice, R. B., G. E. Ferguson, and H. P. Guy. 1968. Erosion from suburban highway construction. Technical Note Proceedings Paper Number 5742, pp. 345-348. Journal of the Hydraulics Division, American Society of Civil Engineering.

Worms, A. J., and Stanley K. Brickler. 1967. Effects of Recreation use and development on water quality. Resource Development Series 12, 9 p. Cooperative Extension Service, University of Kentucky, Lexington.

Zimmerman, Lyle Jerome. 1979. The effects of wastewater effluents on high mountain streams. M.S. thesis, 214 p. University of Colorado, Boulder.

Rocky Mountains | Southwest | Great Plains

Research Note RM-397

April 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Incidence of Western Spruce Budworm Parasites in New Mexico after Aerial Spraying with Carbaryl

J. M. Schmid [1]

SON UNIVERSITY LIBRARY
JAN 11 1982
CH. & AGR. DIV.

Percent parasitism by *Glypta fumiferanae* Viereck decreased significantly in the sprayed areas following application, while *Phytodietus fumiferanae* Rohwer parasitism increased in the same areas. *Apanteles fumiferanae* Viereck increased significantly in two of the sprayed areas the first year after spraying, but percent parasitism generally followed similar patterns in treated and untreated areas. *Ceromasia auricaudata* Townsend decreased significantly in the sprayed areas the first year after spraying, but 2 years after spraying percent parasitism by this species was about equal in both sprayed and unsprayed areas. Other insect parasites exhibited similar trends in sprayed and unsprayed areas during the 2 years following spraying, or their numbers were too meagre to determine a trend.

Keywords: Western spruce budworm, *Choristoneura occidentalis*, insect parasites.

Management Implications

Because the incidence of parasitism for nearly all parasites was not adversely affected by carbaryl spraying, forest managers can use the insecticide without fear of eliminating the parasites.

The parasitic insects associated with the spruce budworms *Choristoneura occidentalis* Freeman and *C. fumiferana* (Clemens) in North America are well known, and their relative abundance has been documented for several geographically distinct areas. Also known, but less well documented, is the effect of insecticides on the incidence of parasitism by these parasites. Several studies (Macdonald 1959, Williams et al. 1969, McGregor 1970,[2] Leonard and Simmons 1974) have noted trends in the incidence of parasitism following the application of insecticides against the host. Such studies have become increasingly important because forest managers feared the insecticide would eliminate the parasites and release the host from their effect, thereby allowing the host population to rapidly attain damaging status again. The study reported herein investigated the effect of carbaryl,[3] applied at the rate of 1.1 kg per hectare, on the incidence of parasitism of western spruce budworm, *C. occidentalis*, larvae in northern New Mexico.

Methods

Study Area

The Forest Pest Management Staff, USDA Forest Service, Southwestern Region, divided the infested host area on the Santa Fe National Forest in Sandoval, Rio Arriba,

[1] *Entomologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is in Fort Collins in cooperation with Colorado State University.*

[2] *McGregor, M. D. 1970. Evaluation of the incidence of western budworm, Choristoneura occidentalis, parasitism 1 year after the application of Zectran insecticide. Unpublished Report, 4 p. USDA Forest Service, State and Private Forestry, Intermountain Region, Missoula, Mont.*

[3] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the USDA to the exclusion of others that may be suitable.*

and Los Alamos counties, New Mexico, into 12 areas for sampling purposes. The areas ranged in size from ca. 1,700 to 4,400 ha. Six areas in the Nacimiento Mountains were sprayed with carbaryl during June 10-17, 1977, while two additional areas in the Nacimiento Mountains and four areas in the Jemez Mountains to the east were left untreated to serve as controls. Areas 1-6 were sprayed and 7-12 were unsprayed. At the time of treatment, larval counts of 14.9 per 100 buds in the sprayed area were not significantly different from the 12.4 per 100 buds in the unsprayed area (Parker et al. 1978). In 1978, one year after spraying, larval densities were 0.9 per 100 buds in the sprayed area and 8.7 per 100 buds in the unsprayed area (Parker et al. 1979). In 1979, 2 years after spraying, the mean larval density for the untreated areas of 9.0 per 100 buds was significantly greater than the density of 0.6 per 100 buds (table 1) for the treated areas (Parker and Ragenovich 1980).

Larval Collections and Analysis

Larvae in stages 3-5 and 5-6 were collected from one arbitrarily selected location in each area. Two separate collections were made because different parasites are present in the earlier instars than in later instars. Larvae in stages 3-5 were collected June 10-13, 1977; June 6-7, 12-14, 1978; and June 12-19, 1979. Larvae in stages 5-6 were collected June 28-29, 1977; June 20, 24-27, 1978; and June 26-July 1, 1979. Because larval development on the west side of the project area (areas 1-6) lagged behind larval development on the east side, collections were first made on the east side and then on the west side to provide more uniformity in the developmental stages and thus comparability between the sprayed and unsprayed areas. Collections during June 10-13, 1977 were scheduled just prior to the carbaryl application in each area.

The goal for each collection from each area was 200 larvae. However, the scarcity of larvae after spraying prevented collection of this number in the sprayed areas, so a crew of workers collected only as many larvae as they could in 3-4 hours. Collections totaled only 35-90 larvae for areas 2 and 5.

Table 1.—Western spruce budworm larvae and pupae per 100 buds (from Parker and Ragenovich 1980)

	1977	1978	1979
Treated areas			
1	20.5	1.3	0.3
2	11.9	0.4	0.5
3	11.7	0.4	1.0
4	17.9	1.2	0.7
5	18.2	1.5	0.1
6	9.0	0.6	0.9
Mean	14.9	0.9	0.6
Untreated areas			
7	2.7	2.0	1.4
8	9.5	10.7	11.8
9	8.7	11.8	11.2
10	17.7	11.5	10.6
11	12.6	10.8	9.2
12	14.3	5.5	9.7
Mean	12.4	8.7	9.0

Larvae were handpicked from branches in the lower crowns of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, and white fir, *Abies concolor* (Gord. and Glend.) Lindl., as well as from mid-crown branches cut from the trees with a pole pruner. Larvae were collected from the lower and middle crowns because it was more efficient, especially after spraying. Because significant differences in percent parasitism between crown levels existed for only *Meteorus trachynotus* Viereck (Hymenoptera:Braconidae),[4] larvae from lower and middle crown branches were pooled together without significantly changing the percent parasitism. A maximum of 15 larvae was collected from a single tree, so that at least 14 trees were sampled to obtain the 200 larvae. Generally more than 50 trees were examined for larvae in sprayed areas where larval numbers became so reduced that the majority of the trees bore no larvae. Because larvae were scarce, collecting with a pole pruner and basket became inefficient and was used sparingly in the sprayed areas.

Larvae were collected mainly from Douglas-fir in the initial 1977 samples. After spraying, larvae were easier to find on white fir in the sprayed areas, so they were collected thereafter mostly from white fir in the treated and untreated areas. Differences in percent parasitism between host species were not recognized until later but, because larvae were collected from the two hosts in the same proportions in the treated and untreated areas, the influence of host differences was probably negligible. It is discussed for those species where it may have had an effect.

The collected larvae were placed in petri dishes with foliage or artificial diet and transported to Fort Collins where they were reared in the laboratory until the adults or parasites emerged. Because some larvae died during handling and transportation, the number of emerging moths and parasites was less than the number of larvae collected in the field.

When most of the moths had emerged, the dishes were examined and the parasites determined. Each parasite was identified to species, if possible. The percent parasitism by each species was then determined and was based on the number of parasites and budworms that emerged—not on the number of collected larvae. Percent parasitism for each species was then tested in an analysis of variance for significant variation associated with treatments and years, $P=0.05$. When significant variation was present between years, Tukey's test was used to determine the relationship between years.

Results and Discussion

Five species of braconids, 17 ichneumonids, and 9 tachinids were reared from the budworms during the 3 years (table 2). Their abundance varied from year to year and between collection sites. The percent parasitism for most species averaged less than 1% each year for the 12

[4] *Schmid, John M. Unpublished data on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

ocumented in previous studies, probably because of its mited abundance.

Results for *Glypta* agree with similar changes observed Macdonald (1959). Macdonald also notes that this ecies exhibited a continuing decline in abundance over e course of the outbreak, suggesting lesser importance r it as an outbreak progresses. The apparent decrease in rasitism in the unsprayed area during the second year ay be further evidence for this type of trend.

One braconid, *Apanteles fumiferanae* Viereck, increased arkedly in two of the six sprayed areas (table 3) the first ear after spraying, but the mean percent parasitism for all eas combined indicates an insignificant increase. multaneously, parasitism by this species in all the nsprayed areas decreased, so the mean percent parasitism r the unsprayed area was significantly less than that of e sprayed areas. During the second year after spraying, rasitism decreased in five of the six sprayed areas while rasitism was increasing in the unsprayed area, so that ean percent parasitism for the sprayed and unsprayed eas was insignificantly different. Previous authors (Macnald 1959, Williams et al. 1969, Leonard and Simmons 974, Hamel 1977) have noted greater percent parasitism *A. fumiferanae* in sprayed areas the first year after raying, but their differences were either not significant, uestionable, or imprecisely related to the insecticide apication. The general trend here is insignificant changes e two post-spray years for all sprayed areas, except for e collection sites in areas 2 and 5 where large changes ocrred the first and second years respectively.

Parasitism increased greatly the first year after spraying the collection locations in areas 2 and 5 where the larvae ere extremely scarce in the 2 years following spraying. acdonald (1959) suggests that *Apanteles* may survive ray programs because they emerge from the host and in cocoons before spraying, and because the moribund st is less likely to contact the residual insecticide. Thus, e high rates of parasitism in areas 2 and 5 could be exained by Macdonald's reasoning. However, the other ur sprayed areas subject to the same conditions exhibited significant changes, so that further explanation is reired. Budworm populations may have to be drastically duced before *Apanteles* parasitism would significantly crease in later years. If budworm populations are reced one year and *Apanteles* populations are unaffected same year, this would create a high ratio of parasite to y in the next generation and increase the probability of ater percent parasitism in the budworm generation.

Parasitism by the tachinid *Ceromasia auricaudata* wnsend decreased significantly in the sprayed area the t year following spraying (table 4),so that parasitism in spray and check areas was not significantly different. multaneously, parasitism by this species in the unayed area did not decline significantly until the second ur. The percent parasitism was the same in both sprayed unsprayed areas in 1979. The trend of this tachinid agrees with the results of Leonard and Simmons (1974) although they lumped all tachinid species into one group. Because *C. auricaudata* was insignificantly more abundant on Douglas-fir than on white fir,[4] collecting more from the white fir after the spraying may have slightly influenced the trend, but was believed to be insignificant because white fir was sampled in the same proportions in the sprayed and unsprayed areas.

The percent parasitism of the other parasites and hyperparasites either exhibited similar trends in both the sprayed and unsprayed areas during the 2 years following spraying or their numbers in each area were too meagre to determine a trend. Trends for the tachinids may have been more noticeable if pupal collections had been made. The braconid, *Meteorus trachynotus* Viereck, was more abundant in the upper levels of the crown,[4] so that sampling of the lower and middle crowns may not have adequately relected its trend. The ichneumonid *Mesochorus vittator* Zetterstedt is a hyper-parasite of *A. fumiferanae*. Percent parasitisms for this species are misleading since the ichneumonid is indirectly responsible for the numbers of budworm destroyed. However, they are retained because they indicate the general abundance of this species.

Conclusions

Percent parasitism by the insect parasites following spraying showed a few increases and decreases but most were not significantly affected. The results agree with Macdonald's 1959 general statement that the parasites were not in danger of elimination by the spray program.

Acknowledgements

E. E. Grissell, P. M. Marsh, and C. W. Sabrosky of the Systematic Entomology Laboratory, USDA, identified the Chalcididae, Braconidae, and Tachinidae, respectively. H. K. Townes of the American Entomological Institute and C. E. Dasch, Muskingum College, generously identified the Ichneumonids, although the author accepts the responsibility for use of the specific name for *Phytodietus*. D. Parker, G. Lessard, and I. Ragenovich, Forest Pest Management, Southwestern Region, USDA Forest Service, greatly assisted this study by assigning their summer crews to help with the collecting.

Work leading to this publication was funded, in part, by the Canada/United States Spruce Budworms, an accelerated research, development, and applications program sponsored by the USDA Forest Service.

Literature Cited

Dowden, Philip B., W. D. Buchanan, and V. M. Carolin. 1948. Natural-control factors affecting the spruce budworm. Journal of Economic Entomology 41:457-464.

Hamel, D. R. 1977. The effects of *Bacillus thuringiensis* on parasitoids of the western spruce budworm, *Choristoneura occidentalis* (Lepidoptera: Tortricidae) and the spruce coneworm, *Dioryctria reniculelloides* (Lepidoptera:Pyralidae), in Montana. Canadian Entomologist 109:1409-1415.

Leonard, D. E., and G. A. Simmons. 1974. The effects of Zectran on the parasitoids of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera:Tortricidae). Canadian Entomologist 106:545-554.

Macdonald, D. R. 1959. Biological assessment of aerial forest spraying against spruce budworms in New Brunswick III. Effects on two overwintering parasites. Canadian Entomologist 91:330-336.

Parker, Douglas L., Robert E. Acciavatti, and Eugene D. Lessard. 1978. Western spruce budworm suppression and evaluation project using carbaryl. 1977 Progress Report 1. USDA Forest Service, Southwest Region, State and Private Forestry, Forest Insect and Disease Management Report 78-11, 136 p. Albuquerque, N. Mex.

Parker, Douglas L., Eugene D. Lessard, and Robert E. Acciavatti. 1979. Western spruce budworm suppression and evaluation project using carbaryl. 1978 Progress Report 2. USDA Forest Service, Southwest Region, State and Private Forestry, Forest Insect and Disease Management Report 79-8, 109 p. Albuquerque, N. Mex.

Parker, Douglas L., and Iral R. Ragenovich. 1980. Western spruce budworm suppression and evaluation project using carbaryl. 1979 Progress Report 3. USDA Forest Service, Southwest Region, State and Private Forestry, Forest Insect and Disease Management Report 80-1. 56 p. Albuquerque, N. Mex.

Williams, Carroll B., Jr., Gerald S. Walton, and Charles F. Tiernan. 1969. Zectran and Naled affect incidence of parasitism of the budworm *Choristoneura occidentalis* in Montana. Journal of Economic Entomology 62:310-312.

canusa

Canada
United States
Spruce Budworms
Program

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some states have restrictions on the use of certain pesticides. Check your state and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or state extension specialist to be sure the intended use is still registered.

Rocky Mountains | Southwest | Great Plains

Research Note RM-398

April 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Plant Species Adaptability on Mine Spoils, in the Southwest: A Case Study[1]

Earl F. Aldon and Charles P. Pase[2]

CLEMSON UNIVERSITY LIBRARY
JAN 11 1982
SCI., TECH. & AGR. DIV.

Five native plant species and one introduced species showed high survival rates (67% to 100%), good vigor, and some spreading 6 years after transplanting on raw mine spoil.

Keywords: Mine reclamation, mine spoils, grasses, shrubs

Techniques for establishing vegetation on mine spoils resulting from the surface mining of coal in the Southwest are advancing rapidly (Aldon 1978, and USDA Forest Service 1979). These techniques have been worked out for a few key native species of both economic and agronomic importance for reclaimed lands (Aldon 1978). However, both state and federal regulations now require that a wide variety of species be reestablished after mining (USDI Office of Surface Mining 1979). To help meet these requirements, a series of species adaptability studies was installed on several mined sites in the early 1970's. Such studies are long term; some argue that plant adaptability in the Southwest isn't certain for 5 or more years (Lavin and Johnsen 1977). However, because reclamation specialists must conform now to requirements set down by law, the need for adaptability information is especially acute.

This note presents the results of a study established in 1973 to evaluate the adaptability of several native grass and shrub species, at the McKinley mine, in west-central New Mexico.

Study Area

The McKinley Mine, 20 miles northwest of Gallup, operates in the Gallup Mesaverde coal field. The climate is semiarid. Annual precipitation averages 10 to 14 inches, a third of which falls as high-intensity rains in July and August. Another third falls as snow from December through March. Dry, windy weather prevails during the spring (< 1.5 inch of precipitation, April-June). Elevation ranges from 6,800 to 7,300 feet. Temperatures reach extremes of -35° to 95° F. Pinyon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodland is the dominant vegetation, occupying the plateaus, benches, mesas, rocky breaks, and steeper slopes. Associated with the trees are several shrubs, such as mountainmahogany (*Cercocarpus montanus*) and cliffrose (*Cowania mexicana*), and a sparse herbaceous understory, including squirreltail (*Sitanion hystrix*). The relatively narrow valleys filled with moderately deep alluvium support big sagebrush (*Artemesia tridentata*) with an understory mainly of western wheatgrass (*Agropyron smithii*) and blue grama (*Bouteloua gracilis*).

[1]The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.

[2]Principal Hydrologist and Principal Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station headquarters is in Fort Collins, in cooperation with Colorado State University.

All plantings in this study were made on unamended spoil material from mining completed in 1969. Spoil characteristics are listed in table 1.

Methods

In August 1973, 14 species of native and introduced perennials listed in table 2 were transplanted at the mine. All seedlings were grown in asphalt-impregnated, paper plant bands which were removed before transplanting. The seedlings were transplanted with soil intact, and were watered in. The transplants were 3-month-old stock. The plot was fenced initially to exclude livestock and game, but fence integrity, at least against rabbits and small rodents, was not maintained. No additional water was provided.

Initial survival was checked in November 1973, and in October or November of 1974, 1978, and 1979.

Because of limited planting stock, some species were not adequately tested, and the limited results are given here for general information only.

Results and Discussion

Of the 14 species tested, 5 native and 1 introduced species have shown considerable promise. These six have high survival rates (67% to 100%), good vigor, and spread by seed or rhizomes into adjacent areas (table 2). The three successful rhizomatous grasses, galleta, western wheatgrass and inland saltgrass, are not highly aggressive, but are spreading slowly, even under the unfavorable but normal rainfall of recent years (table 3). Rubber rabbitbrush and fourwing saltbush are vigorous, averaging between 2 and 3 feet tall, and about 2 feet diameter. Progeny seedlings, while limited, show good vigor, and may be expected to ultimately influence the aspect of the surrounding hillsides. The introduced kochia appears most successful of the shrubs to date, with numerous second and third generation progeny surrounding the test plots. This kochia does not appear weedy, however, and may be worth further testing. Original plants average 13 inches tall and 20 inches diameter (fig. 1).

Transplanting using potted plants was successful with all species except spiny hopsage. The major mortality occurred during the first spring dry period after planting. Plants able to survive this severe drought period apparently were well rooted, and on their way to successful establishment. Sample size of sainfoin, spiny hopsage, and shadscale was too small to be meaningful.

Because of new emphasis on species diversity in reclamation work, additional testing of these and other promising species should continue.

Table 1.—Spoil characteristics at McKinley Mine study site

SAR: 7.21	CEC: 15.0 meq/100 gr
EC: 7.29 mmhos/cm	Na: 35.5 meq/1 Soluble
pH: 6.1	Ca: 25.7 meq/1 Soluble
Organic Matter: 5.1%	Mg: 22.8 meq/1 Soluble
Texture: clay-loam	K: 1.8 meq/1 Soluble
NO_3: 5.6 ppm (1:5 ext.)	Sand: 32.0%
P: 8.8 ppm ($NaHCO_3$ ext.)	Silt: 34.2%
K: 0.24 meq/100 gr (NH_4OAC ext.)	Clay: 33.8%

Table 2.—Success of species transplanted August 23, 1973, on raw spoil, at the McKinley Mine, Gallup, N. Mex.

Species	No. of plants	Percent of original transplants surviving to: Nov. 1973	Oct. 1974	Nov. 1978	Oct 197
Rubber rabbitbrush, *Chrysothamnus nauseosus*	8	100	88	88	[1]8
Galleta, *Hilaria jamesii*	7	100	86	86	[2]8
Alkali sacaton, *Sporobolus airoides*	7	100	100	100	10
Blue grama, *Bouteloua gracilis*	6	100	100	17	
Shadscale, *Atriplex confertifolia*	3	100	67	0	
Sand dropseed, *Sporobolus cryptandrus*	7	86	0	0	
Kochia, *Kochia prostrata*	7	71	71	71	[3]7
Sainfoin, *Onobrychis viciaefolia*	2	50	50	0	
Indian ricegrass, *Oryzopsis hymenoides*	8	38	0	0	
Spiny hopsage, *Grayia spinosa*	2	0	0	0	
Western wheatgrass, *Agropyron smithii*	57	100	100	100	[2]10
True mountainmahogany, *Cercocarpus montanus*	12	100	0	0	
Fourwing saltbush, *Atriplex canescens*	50	80	67	67	16
Inland saltgrass, *Distichlis stricta*	26	38	27	27	[2]2

[1]*Spreading by seedlings. Volunteers are vigorous and we established.*

[2]*Spreading by rhizomes; original plant identity lost.*

[3]*Abundant second and third generation seedlings.*

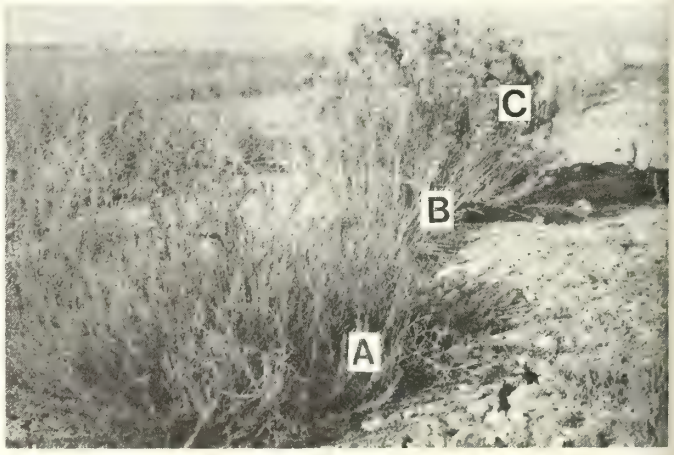


Figure 1.—Vigorous plants of *Kochia prostrata* (A), *Sporobolus airoides* (B), *Chrysothamnus nauseosus* (C) 6 years after transplanting on raw mine spoil at the McKinley Mine.

Table 3.—Precipitation (in inches) at Window Rock, Arizona, 3 miles from the McKinley Mine trial planting site

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1973	0.60	1.26	2.02	0.73	0.96	0.79	1.65	1.48	0.41	0.36	0.69	1.00	11.02
1974	1.44	.39	.19	.44	0	.18	2.90	.17	1.92	3.68	.39	.07	11.98
1975	1.09	1.12	1.61	.59	.09	0	3.87	.62	2.95	0	.80	.28	13.55
1976	.19	.80	.13	.54	.70	.17	2.72	.97	.71	.32	.07	.81	7.46
1977	.38	.61	.95	.13	.25	.52	1.23	2.94	1.14	.49	1.05	.14	10.00
1978	.51	.96	1.64	.28	1.67	0	1.12	1.24	1.10	—	2.78	.31	—
1979	1.64	—	1.45	—	.86	.85	0	.82	.01	.92	.94	1.69	—

Literature Cited

Aldon, Earl F. 1978. Reclamation of coal-mined land in the Southwest. Journal of Soil and Water Conservation 33(2):75-79.

Lavin, Fred, and N. Thomas Johnsen, Jr. 1977. Planting site classification and longtime species adaptation in the pinyon-juniper woodland. U.S. Department of Agriculture, Agricultural Research Service ARS W-45. 25 p. Washington, D.C.

USDA Forest Service. 1979. User guide to vegetation, mining and reclamation in the West. USDA Forest Service General Technical Report INT-64, 85 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

USDI Office of Surface Mining. 1979. Surface coal mining and reclamation operations. Federal Register Vol. 44, No. 50. pp. 14901-15309.

Acknowledgement

This work was conducted in cooperation with Pittsburg and Midway Coal Company. The authors appreciate this company's assistance in furnishing study areas and other facilities and labor for conducting the field investigations.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM–399

April 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Effects of Southwestern Ponderosa Pine Mortality on Potential Wood Product Recovery

Ronald A. Senn, Maggie McMurtray, Peter F. Ffolliott, Gerald J. Gottfried, and Frederic R. Larson[1]

UNIVERSITY LIBRARY
1982

No differences were found between the quality of trees killed by natural causes and of surviving trees. Mortality, primarily caused by lightning, was 18% of annual cubic foot volume increment.

Keywords: Wood properties, tree mortality, *Pinus ponderosa*

While some knowledge of southwestern ponderosa pine (*Pinus ponderosa*) mortality is available (Krauch 1930, Myers and Martin 1963, Pearson 1950, Schubert 1974, Wadsworth 1943), information on the effects of mortality on potential wood product recovery is incomplete. For example, it is not always known whether mortality will alter the proportions, or mix, of wood products that may be obtained by harvesting. This study was conducted to determine if the loss of ponderosa pine trees killed by natural causes (lightning, bark beetles, dwarf mistletoe, etc.) disproportionately affects potential wood product recovery.

Study Areas

Eight watersheds, along the Mogollon Rim, in northern and eastern Arizona, were chosen for the study. Six of the watersheds were on Beaver Creek, approximately 40 miles southeast of Flagstaff (fig. 1). Two watersheds were on the East and West Forks of Castle Creek, 20 miles south of Alpine.

[1]*Senn and McMurtray are Research Assistants and Ffolliott is Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Gottfried is Research Forester, Rocky Mountain Forest and Range Experiment Station, Tempe, in cooperation with Arizona State University. Larson is silviculturist, Rocky Mountain Forest and Range Experiment Station, Flagstaff, in cooperation with Northern Arizona University. Headquarters is in Fort Collins in cooperation with Colorado State University.*

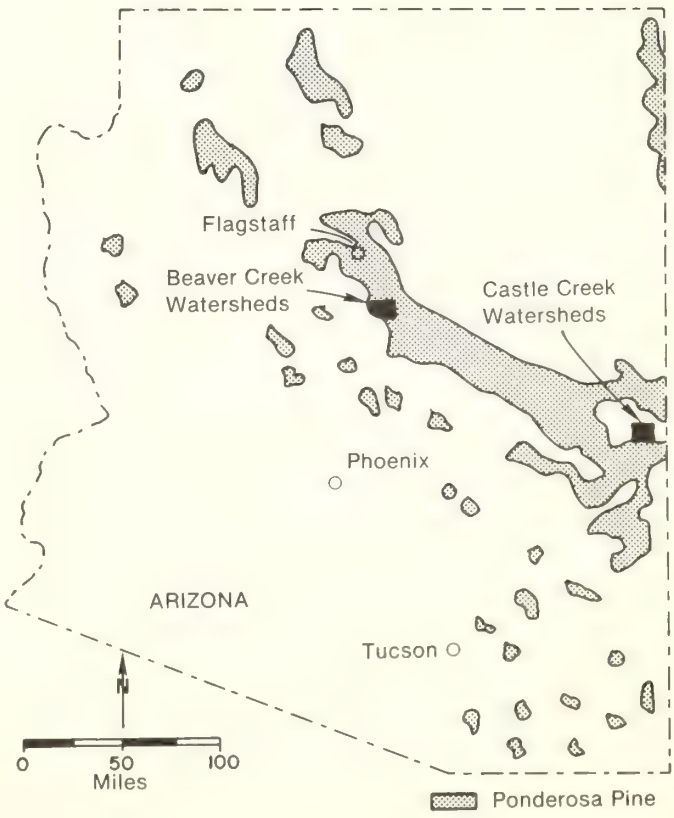


Figure 1.—Study area locations.

The Beaver Creek sites represent cutover stands. The last timber was harvested on four watersheds, in the early 1950's, when 40% of the merchantable volume (trees at least 18 inches d.b.h.) was removed by group selection. The other two watersheds on Beaver Creek were uniformly thinned by group selection and a strip-shelterwood cutting, respectively, in the period 1969-70.

The East Fork of Castle Creek represents virgin conditions. On the West Fork, one-sixth of the forest overstory was clearcut, and the remaining five-sixths were thinned in 1965-66 to achieve optimum growth on residual trees.

All of the study areas predominantly supported ponderosa pine, with Gambel oak (*Quercus gambelii*) and alligator juniper (*Juniperus deppeana*) the primary associates on Beaver Creek, and Douglas-fir (*Pseudotsuga menziesii*) the primary associate on Castle Creek. Soils on the study areas were volcanic, principally basaltic. Slopes varied from 0% to 20%, and elevations ranged from 6,500 to 8,500 feet.

Methods

An initial inventory of the ponderosa pine forest overstories was made during 1963-65. Standard point sampling procedures, using an angle gage corresponding to a basal area factor (BAF) of 25, were used to sample 5,087 living trees (7 inches d.b.h. and larger), at 1,183 permanently established sample points. Basic stem characteristics and defects that affect potential wood product recovery (sweep, crook, scars, and log knots) were recorded.

During 1977-78, the inventory was repeated for each tree previously sampled, using the same procedures. As part of the reinventory, dead trees were noted, with one or more of the following causes of mortality recorded: lightning, bark beetles, dwarf mistletoe, heartrot, snow damage, windthrow, or unknown. The quality of dead trees was based on the earlier inventory.

Potential wood product recovery was estimated using computer program MULTI, a program to analyze wood product potentials in standing trees (Heidt et al. 1971). This program uses data on tree size, and stem characteristics and defects to produce output tables of volumes per acre by grade and size class for each wood product analyzed independently. Wood products considered in this study were commercial poles, saw logs, veneer logs, stud logs, and pulpwood.

Output tables generated from the 1977-78 inventory describing wood product potentials of trees killed by natural causes and of surviving trees were compared. For purposes of comparison, volumes per acre by grade and size class were expressed as a percent of the total volume estimated for each product.

Results and Discussion

No differences were found by chi-square analysis of output tables, for either dead or live trees , among the study areas. Therefore, the data from all study areas were pooled for subsequent analysis.

Most of the trees were killed by lightning (17%), which is common in southwestern ponderosa pine forests (Myers and Martin 1963, Pearson 1950, Schubert 1974). Bark beetles also contributed to mortality, either directly or secondarily by attacking trees weakened by lightning. Snow damage was a primary cause of mortality in small trees.

Average annual mortality of trees 7 inches d.b.h. and larger was 9.6 cubic feet per acre. This value represented about 18% of the gross increment, approximately that reported for southwestern ponderosa pine forests (Schubert 1974). Most of the lost volume occurred in larger trees, generally 22 inches d.b.h. and larger.

In general, there were no significant differences between potential wood product recoveries by volume, grade or class for trees killed by natural causes and for surviving trees, when volumes were expressed as a percent of total volume for each product. This finding can be illustrated by saw log potentials (fig. 2). Further, in both instances, the proportions of tree volumes per acre, by grade and size class potentially suited for wood products, were similar to those previously reported for southwestern ponderosa pine forests (Barger and Ffolliott 1970).

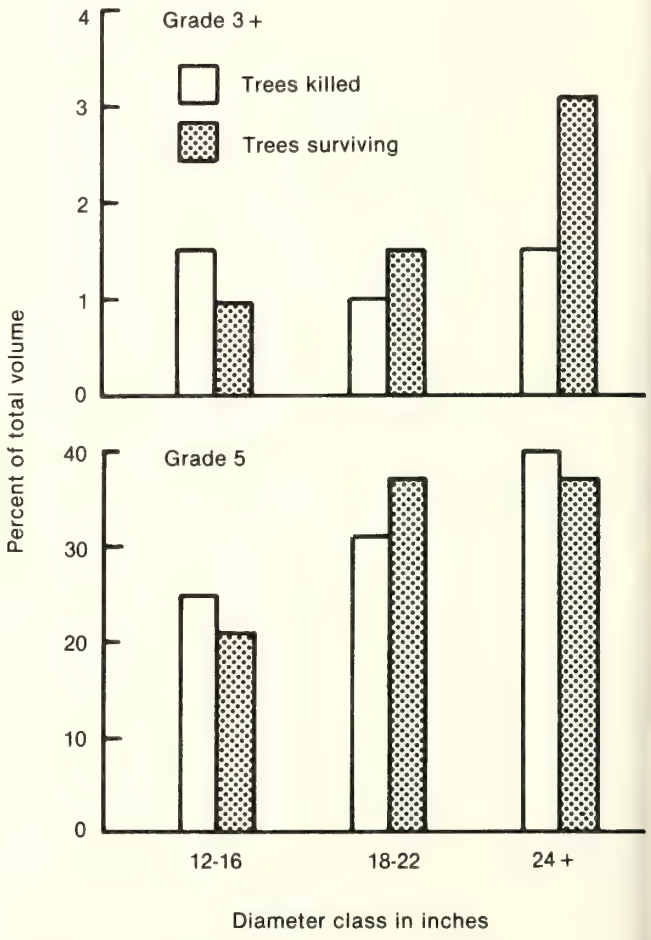


Figure 2.—Saw log potentials of trees killed by natural causes and of surviving trees.

As long as dead stems are standing and are not excluded from consideration for a wood product by definition, recent mortality (up to 10 years) will not affect wood product potentials. However, dead trees eventually deteriorate, reducing net wood product recovery. The policy of reserving two to three pine snags per acre for cavity-nesting birds (Scott 1979) will also reduce net recovery.

The results of this study indicate that mortality has little effect on the proportion of potential wood products recoverable from southwestern ponderosa pine forests.

Literature Cited

Barger, Roland L., and Peter F. Ffolliott. 1970. Evaluating product potential in standing timber. USDA Forest Service Research Paper RM-57, 20 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Heidt, Jack D., Donald A. Jameson, Roland L. Barger, and Bernard J. Erickson. 1971. Determining timber conversion alternatives through computer analysis. USDA Forest Service, Research Paper RM-74, 27 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Krauch, Hermann. 1930. Mortality in cutover stands of western yellow pine. Journal of Forestry 28:1085-1097.

Myers, Clifford A., and Edward C. Martin. 1963. Mortality of southwestern ponderosa pine sawtimber after second partial harvest. Journal of Forestry 61:128-130.

Pearson, G. A. 1950. Management of ponderosa pine in the Southwest. U.S. Department Agriculture, Agricultural Monograph 6, 218 p. Washington, D.C.

Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: The status of our knowledge. USDA Forest Service, Research Paper RM-123, 71 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Scott, Virgil E. 1979. Bird response to snag removal in ponderosa pine. Journal of Forestry 77:26-28.

Wadsworth, Frank H. 1943. Lightning damage in ponderosa pine stands of northern Arizona. Journal of Forestry 41:684-685.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-400

April 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

ON UNIVERSITY LIBRARY
AN 21 1982
& AGR. DIV.

A Collapsible Quail Trap

H. Dwain Smith, Fred A. Stormer, and Ralph D. Godfrey, Jr. [1]

The trap is made of 14-gage galvanized welded wire fabric. The hinged design of the sides with the top allows disassembly into a light weight, flat compact unit, which can be easily transported in quantity.

Keywords: *Callipepla squamata, Colinus virginianus,* quail trap.

Wildlife researchers and game managers occasionally need to trap live birds as part of their official duties. However, it is difficult to transport many bulky cages around to different locations.

Several efforts have been made to solve this problem. Modifications of the Stoddard (1931) quail trap have included changes to facilitate moving and storage. Ligon (1946) developed a collapsible trap from separate panels of twine netting or hardware cloth stretched over and fastened to metal frames. Schultz (1950) described a trap made from poultry netting which can be collapsed by bending the wire netting. More recently, Snyder (1978) describes a collapsible, net-topped trap for bobwhite quail (*Colinus virginianus*).

Most quail-trapping requires an economically constructed trap that can be easily set up, collapsed, transported, and stored, and still is lightweight, strong, and durable. The trap described here meets the requirements and is similar to the one shown by Gallizioli (1965).

Description

The design is patterned after Stoddard's (1931) trap (fig. 1), using 14-gage 1-by-2-inch mesh, galvanized, welded, wire fabric. Twenty traps can be made from a 4-foot-wide, 100-foot roll of wire (fig. 2). Hog-nose rings (we used Seymour H2 shoat rings[2]) are used to hinge the 4 sides and an access door to the top (fig. 3). The short side sections are attached to the top with four rings, and the long side sections are attached with five rings. The outside hog-nose rings are placed through the sides' second mesh to prevent

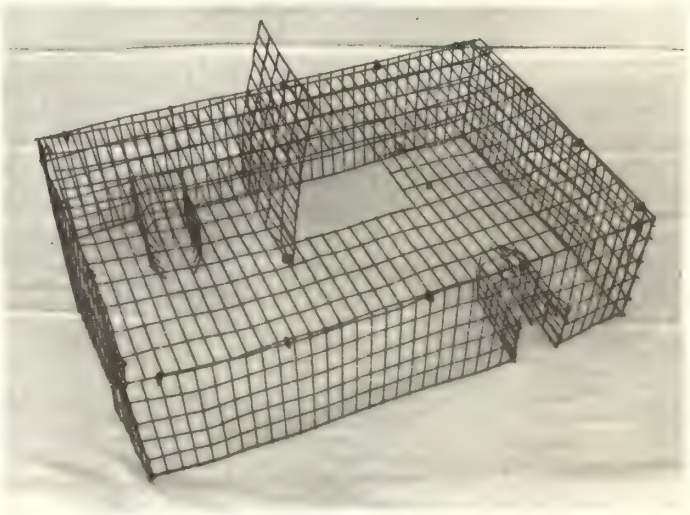


Figure 1.—Collapsible quail trap.

[1] *Biological Technician, Research Wildlife Biologist, and Biological Aid, respectively, at the Station's research work unit at Lubbock, in cooperation with Texas Tech University. Station headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2] *Mention of trade names is for the convenience of the reader and does not imply endorsement by the U.S. Department of Agriculture to the exclusion of equally suitable products.*

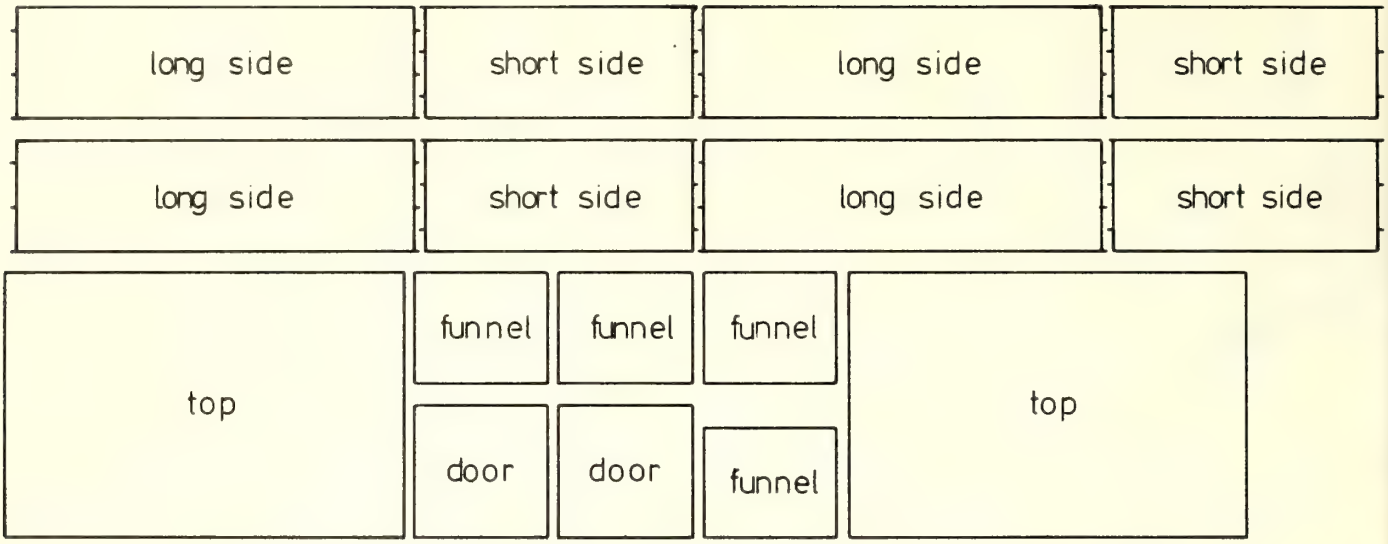


Figure 2.—Method of cutting trap sections for two traps from 4-foot-wide roll of wire fabric.

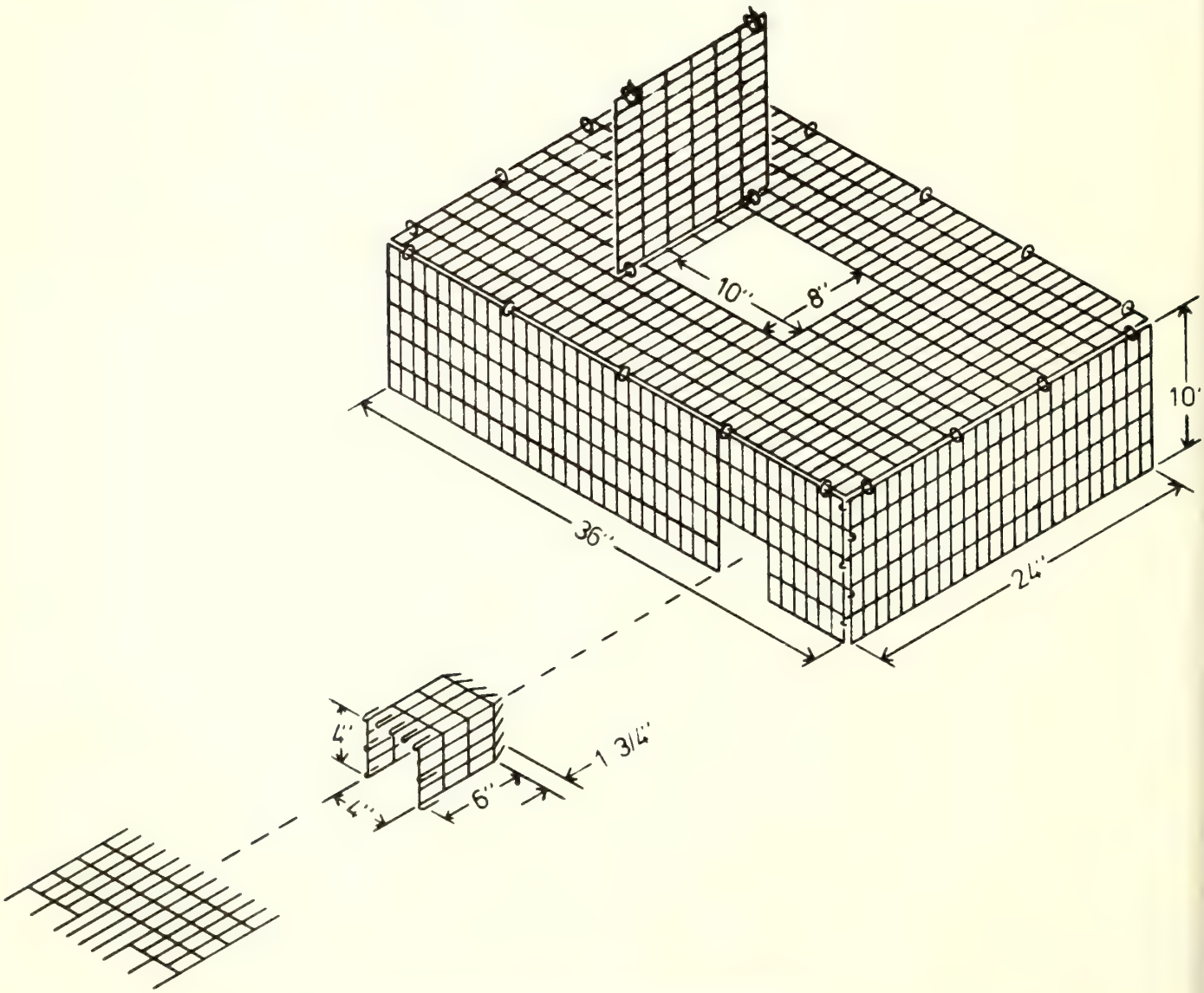


Figure 3.—Schematic of collapsible quail trap.

them from slipping around the corners when the trap is collapsed. The access door is installed with two hog-nose rings and can be latched closed by wire rings made from scrap fabric (fig. 3).

The side sections are cut to leave three 1-inch tangs on the edges that will form the corners of the trap (fig. 3). These are bent into "U-shaped" hooks so that the point will be to the outside of the trap. To set up the trap, the sides are folded down, and the corners secured by alternately placing each hook around the end vertical wire of the adjacent side. When collapsed, the sides can be folded either under or over the top.

The trap has two funnel entrances placed diagonally on each of the two long sides (figs. 1 and 3). To make a funnel, remove cross wires along the sides of the funnel section (fig. 3). After the piece is formed into a 10-inch-long, three-sided tunnel, the exterior wire tangs are shaped outward into open hooks, and the interior tangs are turned inward to form the trap funnel (fig. 3). In the erected trap, the funnels are secured in the trap by the hooks.

A bead of silicone glue applied to sharp wire ends protects field personnel and trapped quail from scratches and cuts. Personnel constructing the traps should wear leather gloves and long-sleeved shirts.

Discussion

This trap has been used successfully to capture 390 scaled quail (*Callipepla squamata*) (0.76 quail per trap day) during studies of scaled quail habitat requirements, food habits, and reproductive ecology. Three quail died as a result of trapping; one had a leg injury and was sacrificed, and the others probably died from exposure.

The collapsible trap is reasonably economical to construct. Twenty traps cost about $80 for materials and required 16 hours of labor to construct.

The trap is lightweight (4 pounds), durable, and easily set up and collapsed. Traps left outside for more than 1 year have not rusted or otherwise deteriorated. The trap is strong enough to support heavy limbs placed over it to provide shade and thwart disturbance by cattle. When collapsed, a trap measures 24 by 36 by 0.5 inches. More than 200 can be transported in a one-half-ton pickup. When removed, the trap funnels can be stacked by resting one inside the other.

Literature Cited

Gallizioli, Steve. 1965. Quail research in Arizona. Contribution from Federal Aid Project W-78-R, 11 p. Arizona Game and Fish Department, Phoenix.

Ligon, J. Stokely. 1946. Upland game bird restoration through trappings and transplanting. 77 p. New Mexico Game and Fish Commission, Albuquerque.

Schultz, Vincent. 1950. A modified Stoddard quail trap. Journal of Wildlife Management 14:243.

Snyder, Warren D. 1978. The bobwhite in eastern Colorado. Technical Publication 32, 88 p. Colorado Department of Natural Resources, Denver.

Stoddard, Hubert L. 1931. The bobwhite quail: Its habits, preservation and increase. 559 p. Charles Scribner's Sons, New York, N.Y.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Mountains Southwest Plains

Research Note RM-401

May 1981

USDA Forest Service
Rocky Mountain Forest and
Range Experiment Station

Key to Large Lepidopterous Larvae on New Foliage of Douglas-fir and True Firs

UNIVERSITY LIBRARY
AN 21 1982
H. & AGR. DIV.

V. M. Carolin, Jr., and Robert E. Stevens[1]

Presents a key primarily for field use, emphasizing characters visible with a hand lens. The key separates larvae of associates of the western spruce budworm, *Choristoneura occidentalis* Freeman, in advanced instars.

Keywords: Lepidoptera, larvae, *Choristoneura occidentalis, Pseudotsuga menziesii, Abies* spp.

Field workers involved in surveys or related activities on western spruce budworm often collect and count large larvae on expanding or expanded new foliage of host trees. Other foliage-feeding Lepidoptera occur on the new foliage, and it is important to be able to separate and distinguish between the various species.

This key is the second prepared by the authors for trial use by survey, control, and research personnel working on western spruce budworm. The previous one (Carolin and Stevens 1979) dealt with small larvae in opening buds and new shoots of Douglas-fir and true firs. Both keys are based primarily on notes prepared by the senior author during field studies on spruce budworm in Oregon and Washington during the period 1955-1962. This key to larger larvae includes new material from the Southwest, and experience has shown it is useful throughout the range of western spruce budworm. Also provided (table 1), is a summary of hosts and western distribution of included species.

This key is meant for larvae exceeding 10-12 mm in length; the features used in it can easily be seen with a 10X hand lens. Coloration and markings on the head, prothoracic shield, and the dorsal surface in general are particularly useful in recognition of these larger larvae. Size and shape are easier to define than in the smaller larvae found in opening buds and new shoots. A few species retain a generally similar appearance throughout the larval stage, but most develop new and often striking characteristics as they approach larval maturity. Hence the need for a second key.

As with the previous key, only lepidopterous larvae are included. Hymenopterous species noted in the introduction to the first key change little during development, but are easier to recognize because of their larger size. Some sawfly larvae in the genus *Neodiprion* which feed in colonies on older foliage (only one species of *Neodiprion*, still unidentified, is known from new foliage) wander as they approach maturity and may be found on the new foliage. They can be recognized by the number of abdominal prolegs, body wrinkles, and shape of the head. Figure 1 compares a typical lepidopterous larva and a *Neodiprion* sawfly larva, and also shows major characteristics used in the key.

The users of a larval key often have difficulty recognizing a variety of patterns of longitudinal lines and stripes. The markings are sometimes more striking than can be adequately described. Figure 2 illustrates several of these. Together with larval size and shape, recognition of these patterns simplifies separation of these particular species.

We solicit additions to the key and comments about it. Additions should be in the form of authoritatively identified adults reared from larvae, the characteristics of which have been duly recorded during the rearing process. The junior author will arrange for determination of specimens not previously identified.

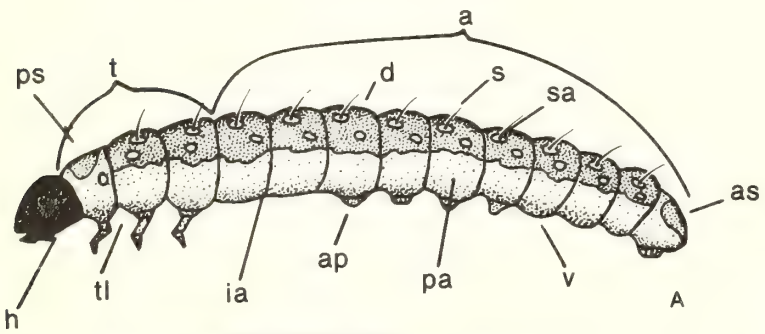
At the end of a trial period, we will revise the keys and add illustrations that will help users in picking out diagnostic characters. We hope the product will be of general utility to workers concerned with insects feeding on the new foliage of Douglas-fir and true firs.

[1]*Carolin, now retired, was an entomologist with the Pacific Northwest Forest and Range Experiment Station, Portland, Oreg. Stevens is an entomologist with the Rocky Mountain Forest and Range Experiment Station, in Fort Collins, in cooperation with Colorado State University.*

Table 1.—Summary of species contained in key to large lepidopterous larvae on new foliage of Douglas-fir and true firs

Family	Species	Western distribution
Geometridae	*Enypia griseata* Grossbeck	Southwest
	Enypia sp. nr. *griseata* Grossbeck	Pacific slope[1]
	Eupithecia annulata (Hulst)	Pacific slope, northern Rocky Mountains
	Eupithecia catalinata McDunnough	Southwest
	Lambdina fiscellaria lugubrosa (Hulst)	Pacific slope, northern Rocky Mountains
	Melanolophia imitata (Walker)	Pacific slope
	Nepytia phantasmaria (Strecker)	Pacific slope
	Stenoporpia sp.	Pacific slope
Gelechiidae	Unidentified species	Pacific slope
Noctuidae	*Achytonix epipaschia* (Grote)	Pacific slope, Southwest
	Feralia deceptiva McDunnough	Pacific slope
	Xylomyges simplex (Walker)	Pacific slope, Southwest
Plutellidae	*Ypsolophus nella* (Busck)	Southwest
Pyralidae	*Dioryctria reniculelloides* Mutuura and Munroe	Pacific slope, northern Rocky Mountains
Tortricidae		
Olethreutinae	*Griselda radicana* (Heinrich)	Pacific slope, Rocky Mountains, Southwest
	Zeiraphera hesperiana Mutuura and Freeman	Pacific slope, Southwest
Tortricinae	*Acleris gloverana* (Walsingham)	Pacific slope, northern Rocky Mountains
	Archips sp.	Pacific slope
	Argyrotaenia dorsalana (Dyar)	Pacific slope, Southwest
	Argyrotaenia klotsi Obraztsov	Southwest
	Argyrotaenia provana (Kearfott)	Pacific slope, Southwest
	Choristoneura occidentalis Freeman	Pacific slope, Rocky Mountains, Southwest
	Choristoneura retiniana (Walsingham) = *viridis* Freeman	Pacific slope
	Choristoneura n. sp.	Pacific slope

[1]*Used here to include the area west of the Continental Divide between British Columbia and northern California.*



LEGEND

a	abdomen	ps	prothoracic shield
ap	abdominal proleg	s	seta
as	anal shield	sa	setal area
d	dorsum	t	thorax
h	head	tl	thoracic leg
ia	intersegmental area	v	venter
pa	pleural area		

Figure 1.—Comparison of: (A) typical lepidopterous larva, and (B) a hymenopterous larva in the sawfly genus *Neodiprion*. (3.5X)

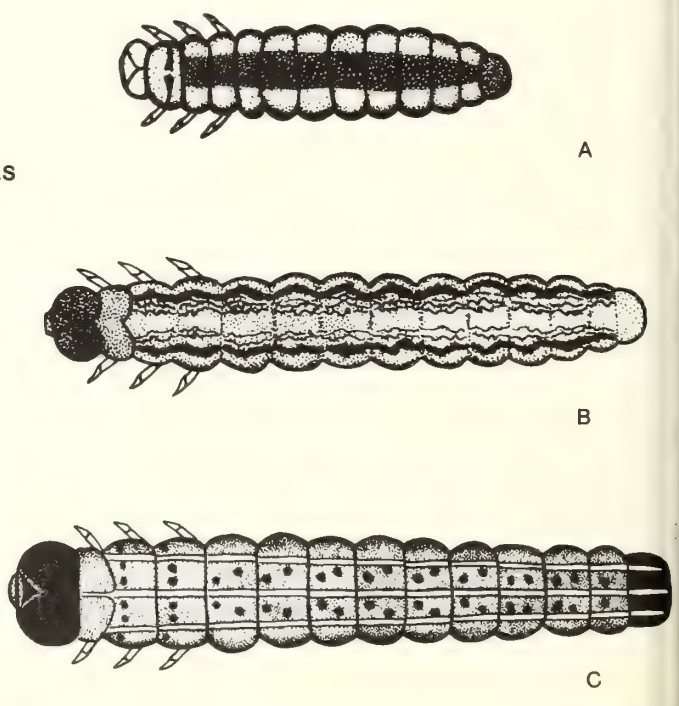


Figure 2.—Examples of longitudinal dorsal markings: (A) central stripe (*Zeiraphera hesperiana*); (B) irregular lines (*Dioryctria reniculelloides*); (C) regular lines (*Xylomyges simplex*). (3.5X)

Key to Large Lepidopterous Larvae on New Foliage of Douglas-fir and True Firs

A. Larvae with two pairs of false legs, moving with an inching or looping motion based on use of anal prolegs ..... Section I. Geometridae

B. Larvae with five pairs of false legs, moving at a constant pace, but often wiggling violently when disturbed ..... Section II. Tortricidae,[2] Gelechiidae, Plutellidae, Pyralidae, and Noctuidae.

Section I. Geometridae

1. Dorsum marked with longitudinal lines or stripes 4
1. Dorsum without longitudinal lines or stripes; pleural areas with longitudinal lines or stripes 2
2. Head light brown, unicolorous; dorsum orange-red-brown; pleural areas with yellow lateral stripe; venter yellow; body length 25-35 mm ..... *Stenoporpia* sp.
2. Head whitish but mottled with light brown, black dots visible above; dorsum variously colored, with setal areas appearing as four black dots on each segment; pleural area with thick dark brown line, often divided, and with four or five thin wavy lines below it; species earlier found on new shoots but at these stages feeding on old foliage 3
3. Head with brown streaking as well as mottling, four black dots visible above; dorsum pale orange-brown, or pale green with orange-brown in intersegmental areas; body length 12-20 mm ..... 4th instar *Lambdina fiscellaria lugubrosa*
3. Head uniformly mottled with 10 black dots visible above; dorsum light yellow-brown to gray-brown, with orange-brown on prothorax and in intersegmental areas; body length 18-30 mm ..... 5th instar *Lambdina fiscellaria lugubrosa*
4. Head orange-red; dorsum orange-red with three longitudinal purple lines; body length 10-14 mm ..... *Eupithecia* spp.
4. Head green or yellow-brown; dorsum with two longitudinal whitish lines; pleural areas with whitish lines 5
5. Head pale yellow-brown; dorsum light bluish green with wide whitish yellow lines; pleural areas with two whitish yellow lines, one wide and one narrow; body length 16-25 mm. Inland forests ..... *Enypia* spp.
5. Head green; dorsum apple green to dark green with white lines; pleural areas with a single yellow line or stripe. Coastal forests. 6
6. Head green with no markings; body length 20-37 mm; feeds mostly on old foliage ..... *Melanolophia imitata*
6. Head green with 10 black dots; body length 20-28 mm ..... *Nepytia phantasmaria*

[2]*Includes Olethreutidae as a subfamily, Olethreutinae, per revised checklist of North American lepidoptera (Hodges et al., 1981.*

Section II. Tortricidae,[2] Gelechiidae, Plutellidae, Pyralidae, and Noctuidae

1. Dorsum prominently marked with longitudinal lines or stripes 11
1. Dorsum not prominently marked with longitudinal lines or stripes; pleural areas and venter often a lighter color 2
2. Head, prothoracic shield, and remainder of body emerald green; prothoracic shield collar-like; setal areas and anal shield inconspicuous; body form slender, length 12-18 mm ..... *Argyrotaenia provana*
2. Head and prothoracic shield colored otherwise; body form stout or moderately stout, except for *Argyrotaenia dorsalana* 3
3. Head and prothoracic shield yellow-brown, light brown, or chestnut brown 5
3. Head, prothoracic shield, and outside of thoracic legs jet black; setal areas inconspicuous 4
4. Body yellow-green to green; prothoracic shield sometimes pale in front; body length 10-14 mm ..... penultimate instar *Acleris gloverana*
4. Body lemon yellow; prothoracic shield solid black; body form terete and stout; body length 12-16 mm ..... *Archips* sp.
5. Head pale brown to chestnut brown with no dark markings above; prothoracic shield various; setal areas various 7
5. Head chestnut brown with two dark triangles on each side, dorsally; prothoracic shield dark brown to black; setal areas conspicuous 6
6. Dorsum olive brown to dark brown, with prominent ivory setal areas; pleural areas and venter pale yellow to light tan; body length 10-16 mm ..... 5th instar *Choristoneura occidentalis*
6. Dorsum lime green with olive tinge, with pale yellow setal areas; pleural areas and venter usually greenish but sometimes yellowish; body length 9-15 mm ..... 5th instar *Choristoneura retiniana (= viridis)*
7. Head mostly light brown, but with two-toned appearance from greenish color around labrum or dark streak on lower part of head; prothoracic shield indistinct, concolorous with body; body pale green with small yellowish setal areas and with yellow in intersegmental areas; body form slender, length 10-14 mm ..... *Argyrotaenia dorsalana*
7. Head brownish, unicolorous; prothoracic shield distinct, different color than body; body stout, length greater than 14 mm 8
8. Body reddish brown to olive brown above, with large ivory setal areas and large anal shield; head and prothoracic shield orange-brown to chestnut brown 10
8. Body grass green, with small or moderately large pale setal areas; head usually a lighter brown; prothoracic shield a different color than head 9
9. Head yellow-brown at start of stadium, later becoming chestnut brown; prothoracic shield pale brown to transparent, but marked with a thick black line at

rear of shield; setal areas pale but conspicuous at start of stadium, later becoming inconspicuous; body length 12-16 mm ..... last instar *Acleris gloverana*

9. Head light tan; prothoracic shield pale yellow-brown with two black dots at base on each side of split in shield; setal areas pale yellow and conspicuous; anal shield oblong-orbicular, pale yellow; body length 16-22 mm ..... last instar *Choristoneura retiniana (= viridis)*

10. Larger larvae; setal areas oblong; anal shield oblong-orbicular, ivory to pale yellow; body length 17-28 mm ..... last instar *Choristoneura occidentalis*

10. Smaller larvae; setal areas round; anal shield round, ivory to light brown; dorsum occasionally with two very fine white lines; colors brighter than in *occidentalis*; body length 12-18 mm ..... last two instars *Choristoneura* n. sp.

11. Dorsum various shades of yellow, orange, red, or brown, marked with either lines or stripes 17

11. Dorsum various shades of green, sometimes with brownish tint; marked with white or brown longitudinal lines 12

12. Dorsum marked with white longitudinal lines 13

12. Dorsum marked with three broad longitudinal brown lines; head brown; prothoracic shield green; body length 12-18 mm ..... *Argyrotaenia klotsi*

13. Dorsum with five white longitudinal lines, the lowermost ones bordered by a lateral red line; head light greenish brown; body length 30-37 mm ..... *Feralia deceptiva*

13. Dorsum with three white longitudinal lines; head various colors 14

14. Head black, globose, and wider than body; prothoracic shield very pale; body light green to olive, setal areas large and black 16

14. Head green to brown, no wider than body; prothoracic shield either invisible or pale brown; body apple green, setal areas small and black 15

15. Head green, narrower than body; body bright green, sometimes with blue tinge, setal areas inconspicuous; wide longitudinal lines extended over prothorax and anal segment; body length 10-17 mm ..... penultimate instar *Achytonix epipaschia*

15. Head brown, as wide as body; body pale green, setal areas conspicuous; central longitudinal line extended over prothoracic shield, and all three lines extended over brown anal segment; body length 18-22 mm ..... last instar *Achytonix epipaschia*

16. Anal shield very pale; dorsum olive (brownish green), setal areas scarcely raised; body length 10-14 mm ..... *Xylomyges simplex*

16. Anal shield dark brown, occupying whole segment; dorsum a mottled green, setal areas large and raised; body length 15-30 mm ..... last two instars *Xylomyges simplex*

17. Large white eyespot around lateral seta on 8th abdominal segment; two irregular (undulating) white lines running through dorsocentral setae; head and prothoracic shield light brown 21

17. No eyespot on 8th abdominal segment; longitudinal lines or stripes with essentially even margins 18

18. Body form stout; head wider than long; head and prothoracic shield orange brown to chestnut brown, the latter usually margined at the rear with a black line; dorsum pale yellow to orange yellow, with a broad central olive brown or chocolate brown stripe; body length 12-15 mm ..... last instar *Zeiraphera hesperiana*

18. Body form slender; head no wider than long, pale brown to chestnut brown; dorsum with longitudinal lines or thin stripes 19

19. Dorsum purplish, with two narrow and one broad yellowish green longitudinal lines on either side of the dorsal midline; setae and setal bases black and conspicuous; venter light greenish white; body length 9-12 mm. Larvae web ends of new needles together and feed inside enclosure ..... *Ypsolophus nella*

19. Dorsum yellow or brown; setae and setal bases inconspicuous 20

20. Body pale yellow to bright yellow; dorsum marked with three orange-red or orange-brown light to heavy lines; body length 9-12 mm ..... last instar *Griselda radicana*[3]

20. Body pale brown; dorsum marked with three red-lavender stripes; body length 12-14 mm ..... unidentified species Gelechiidae

21. Dorsum pinkish brown or reddish brown; an irregular white line in pleural area; body length 10-15 mm ..... penultimate instar *Dioryctria reniculelloides*

21. Dorsum pale yellow-orange to orange-red; one irregular chocolate brown stripe on each side of dorsum; body length 16-20 mm ..... last instar *Dioryctria reniculelloides*

[3]Griselda radicana *later enters a 3- to 4-week nonfeeding period in which it loses its markings and coloration, becoming a whitish nondescript larva hiding among foliage debris. Pupation follows.*

Literature Cited

Carolin, V. M., Jr., and Robert E. Stevens. 1979. Key to small lepidopterous larvae in opening buds and new shoots of Douglas-fir and true firs. USDA Forest Service Research Note RM-365, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Hodges R. W., et al. 1981. Checklist of the Lepidoptera of America North of Mexico. The Moths of North America. E. W. Classey Ltd., and R. B. Publications, Inc., London, England.

canusa

Canada
United States
Spruce Budworms
Program

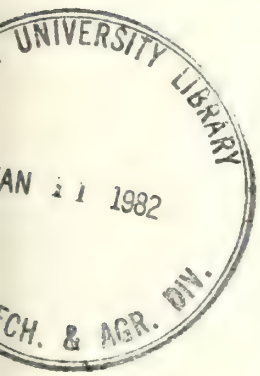
Mountains Southwest Plains

Research Note RM-402

May 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Preliminary Burning Prescriptions for Ponderosa Pine Fuel Reductions in Southeastern Arizona



Michael G. Harrington[1]

Natural ponderosa pine fuels can be safely burned with air temperatures between 55° and 75° F, relative humidities between 25% and 50%, and windspeeds less than 10 miles per hour. The moisture content of the surface L layer needles should be between 5% and 10%. Total fuel reduction will depend on H layer moisture. Burning under these conditions will lessen the wildfire hazard by reducing fuel loadings, thinning the stand, removing ladder fuels, and raising the canopy level.

Keywords: Fuel reduction, hazard reduction, burning prescription, *Pinus ponderosa* var. *arizonica*.

Management Implications

The primary purpose of prescribed burning under natural stand conditions, in the ponderosa pine (*Pinus ponderosa* var. *arizonica*) zone of the Santa Catalina Mountains, is to reduce the fire hazard caused by 70 years of fuel buildup, and by high lightning and human-caused ignition risks. Because damp, cool fall weather often leads to inadequate burning treatments, summer burning was attempted as an alternative. Light, surface fuels were effectively consumed by fire within a few days after heavy rainshowers. This reduced the ignitability and rate of spread potential, at least temporarily. Canopy, ladder, and additional ground fuels were reduced by burning near the drier prescription limits. These reductions further decreased potential fire intensity, total energy release, and unfavorable fire effects.

Prescribed burning reduced heavy fuels to varying degrees. Fuel groups were affected more than single fuel pieces. In general, under similar conditions, most heavy woody material will be at least charred, if not greatly reduced, making it less ignitable.

Few control problems were encountered while burning during the summer. However, during these initial fuel reduction burns, backing fires are essential for control and reduction of damage.

Introduction

Heavy recreation use in the Santa Catalina Mountains in southeastern Arizona has considerably increased the risk of human-caused fires. In the ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) zones, above 6,000 feet, the number of human-caused fires has increased three-fold from the 1960's to the 1970's.[2] These forest zones also experience a high incidence of lightning fires with a yearly average of one fire for every 1,200 acres.[2] Because of effective fire suppression, many of the ponderosa pine stands in these mountains have been untouched by large-scale fires for 65-75 years,[3] leading to the accumulation of abundant natural fuels. Steep slopes and overstocked groups of pine saplings add to the risk, creating a potentially dangerous fire situation. The potential damage of wildfire is increased because of radar equipment and numerous mountain home developments within these hazard zones. All these factors suggest a need for fuel reduction measures.

[1]*Research Forester, Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Tempe, in cooperation with Arizona State University. Headquarters is in Fort Collins in cooperation with Colorado State University.*

[2]*Data on file, Santa Catalina Ranger Station, Tucson, Ariz.*
[3]*Data on file, Fuel Management Project, RM-2108, Tempe, Ariz.*

In southwestern ponderosa pine forests, most prescribed burns are conducted in the fall for safety and better predictability. In the fall, after fuels have been dampened and temperatures and humidities have moderated, fires burn with less intensity and are generally less hazardous than during the warmer, drier summer.

Occasionally, the weather and fuels remain too dry into the autumn, to permit favorable, prescribed burning. Conversely, summers are often followed by damp, cool fall weather which can minimize the effectiveness of prescribed fires, or prevent fire treatments entirely. If weather conditions postpone fuel reduction programs, having another season to conduct prescribed fires may be helpful.

July and August are a potentially good prescribed burning period. In Arizona, late spring is normally hot and dry, with little rain. In midsummer, moist air moves north into this region, causing frequent thunderstorms. Fuels are again dampened, relieving the extreme fire danger and possibly permitting burning.

The primary purpose of this study was to begin to develop midsummer burning prescriptions for ponderosa pine stands in southeastern Arizona. Fuel moisture contents were studied closely to determine their effects on fuel reduction by burning.

Study Area

The study area was on southwest facing, 30-50% slopes, in the Santa Catalina Mountains, 10 miles northeast of Tucson, Ariz. At this 8,000 foot elevation, annual precipitation averages 30 inches. About 10% of this precipitation falls in spring, with the other 90% equally distributed throughout summer, fall, and winter. The forests are composed primarily of uneven-aged stands with even-aged groups (fig. 1), typical of much of Arizona's ponderosa pine. The stand is predominantly 5-needle ponderosa pine, with a mixture of Douglas-fir, southwestern white pine (*Pinus strobiformis*), and silver leaf oak (*Quercus hypoleucoides*). The forest floor fuels are mostly needles, with naturally fallen woody material, including scattered, downed logs.

Figure 1.—Ponderosa pine stand with two maturity groups, open group on the right and closed group on the left.

Methods

The study site was divided into three areas, about 3 acres each. Six plots were established within each of the areas. Because the stand consisted of two distinct maturity groups (fig. 1), three plots were located in each group, in each area. The open groups were characterized by large, old growth ponderosa pine, and the closed groups, commonly called "dog-hair thickets," consisted of dense, overstocked clumps of ponderosa saplings. Criteria for plot location were homogeneity and good representation of both stand and fuels.

Each plot consisted of a non-random 3 by 3 grid, with each of the nine points being sample points spaced 20-25 feet apart, depending on group sizes. To estimate the forest floor needle and woody fuel components smaller than 1 inch in diameter, a 1-square-foot sample from each of the nine sample points was cut to mineral soil, bagged, and returned to the lab for oven-dry weight determination. Four of the nine collections were separated into three distinct stages of forest floor decomposition. The L layer (litter) is the newly fallen, surface fuel. The F layer (fermentation) consists of material in the early stages of decomposition and weathering. H layer (humus) fuels are in the advanced stages of decomposition, immediately above mineral soil, where separate fuel components are difficult to distinquish. The weights of specific components of each layer (needles, 0- to 0.25-inch twigs, 0.25- to 1-inch twigs, oak leaves, bark, and cone parts) were determined. Sackett's (1979) collection and laboratory methods were followed. Four forest floor depth measurements were taken for each square foot of material removed.

Downed, woody fuel with diameters between 1 and 3 inches was sampled along three transects running across the plot between the sample points. Intercepts of fuels in this size class were counted, and a weight per area was determined using Brown's (1974) method.

The length and mid-diameters of all woody fuel pieces greater than 3 inches in diameter were measured within a 0.05-acre circular sample. Only that portion of fuel pieces which fell within the 0.05 acre was measured. Fuel volumes were computed using length and diameter measurements, and weights were determined using accepted densities of either sound or rotten woody material sampled.

To estimate stand characteristics in each plot, the diameter at breast height and species of each tree occurring within a 0.067-acre circular sample were recorded.

A weather station equipped with a recording rain gage and hygrothermograph was set up adjacent to area 1. Fuel moisture stick values, in addition to temperature, precipitation, and relative humidity, were also measured at a permanent fire weather station, Palisades, a few hundred yards from the study site.

Fuel was sampled to determine moisture content during the burning. Six samples each of L layer needles, F layer needles, and H layer humus were collected from each maturity group. Each sample consisted of a composite of four or five subsamples. Also, woody material from two sound and two rotten logs were collected from the closed and open groups, immediately before burning. The upper 5 inches of the log were sampled with separations made for the surface 1 inch, 1-3 inches, and 3-5 inches. Moisture contents were determined gravimetrically.

Figure 2 shows the relationship of July and August precipitation to the three burning dates. A 15-day rainless period ended on July 17, beginning 5 rainy days. Area 1 was burned on July 24, 3 days after these rains. Four days after two brief rains, the second area was ignited (August 3). Finally, area 3 was burned 4 days after a 2-week period of rain. Backing fires were used almost exclusively, with the exception of one series of short strip head fires required at the end of one day.

During burning, flame lengths were estimated, and rates of fire spread were measured periodically. Fireline intensities were estimated using the inverse of the formula, Flame Length = 0.45 (Intensity$^{0.46}$) (Byram 1959). After the burning, fuels were collected near established points, using the same sampling scheme as in the preburn sampling. The distances that the lower portion of the crowns were raised were visually estimated after the scorched needles had fallen.

Analysis

Fuel moisture contents for the three areas within maturity groups were statistically compared using analyses of variance and linear contrasts. This method also was used to compare the reduction of forest floor material ≤1 inch in diameter, needle fuels, and total fuels, resulting from the three fires. Too much variation between plots because of light sampling intensity, made it impossible to statistically compare reduction of other fuels.

Results and Discussion

Stand and Fuel Description

Because of differences in tree sizes and spacings between the open and closed groups (fig. 1), data from the two maturity groups were evaluated separately. Group characteristics were as follows:

	Open groups	Closed groups
Average d.b.h. (inches)	5.2	2.5
Density (trees per acre)	603	3,512
Basal area (square feet per acre)	206	186

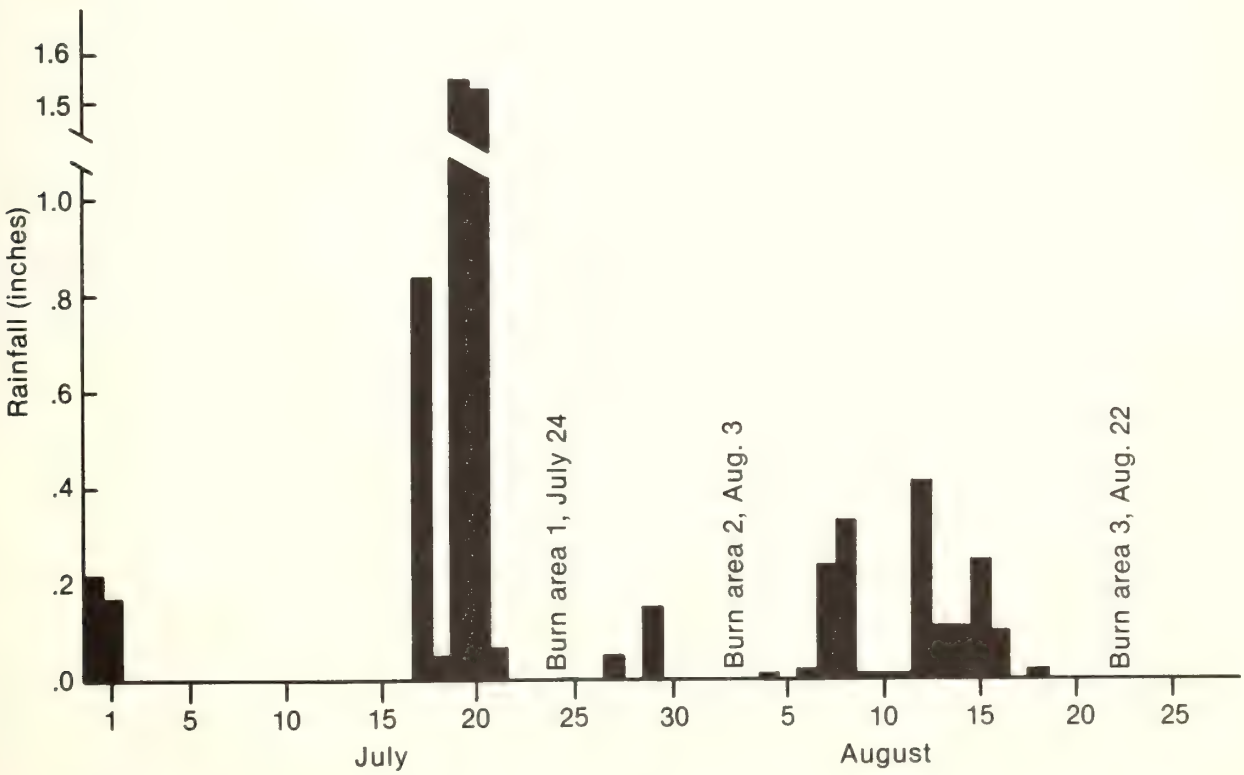


Figure 2.—Three prescribed burns in relation to July and August precipitation.

Ponderosa pine is the obvious dominant in both maturity groups. In the open and closed groups, ponderosa pine makes up 65% and 87% of the trees per acre, respectively, and 91% and 79% of the basal area, respectively. Southwestern white pine, which appears to be increasing because of the absence of fire, is next in number of trees per acre, but the trees are relatively small. The closed groups have more and larger oaks as well as a few Douglas-firs.

Fuel weights in each maturity group were as follows:

	Open groups	Closed groups
	-- tons per acre --	
Needles/humus	24.2	19.9
0- to 0.25-inch twigs	0.3	0.4
0.25- to 1-inch twigs	1.0	1.0
Miscellaneous	3.2	2.1
≤1-inch material (forest floor)	28.7	23.4
1- to 3-inch woody material	0.7	0.9
>3-inch woody material (sound)	1.0	4.0
>3-inch woody material (rotten)	3.1	6.0
Total fuel loading	33.5	34.3

Burning Conditions and Fire Behavior

The weather conditions and fire behavior observations for the three burns are shown in table 1.

Weather and fire behavior differences among the three burns were slight, except for relative humidities. Flame lengths and calculated fireline intensities were somewhat greater in area 3 than area 2. Area 1 fires had the lowest intensities. These intensity differences likely resulted from fuel moisture differences (table 2).

Area 1 was subjected to the greatest amount of rain and least number of effective drying days before burning, and, in general, had much wetter fuels. Area 2 had little rainfall immediately preceding burning, and the drying days were sufficient to reduce moisture in most fuels to the lowest of three areas. Area 3 fuels were influenced by a prolonged rainy period, but two extremely dry days, with steep vapor pressure gradients, just prior to burning, dried the light surface fuels to the lowest moisture content of the three areas, and dried other fuels to a lesser degree.

Table 2.—Average fuel moistures (in percent) and standard deviations during three prescribed burns ($n = 6$ samples)

Maturity group	Area	L-needles	F-needles	H-humus
Open	1	6.4 ± 1.8a[1]	23.1 ± 11.2a	88.4 ± 34.1a
	2	6.0 ± 0.8a	6.8 ± 1.6b	21.4 ± 5.0b
	3	4.7 ± 1.3a	8.6 ± 3.3b	32.4 ± 10.7b
Closed	1	9.2 ± 1.5a	64.1 ± 16.5a	79.0 ± 28.9a
	2	7.6 ± 1.6a,b	10.7 ± 0.9b	30.3 ± 18.2b
	3	6.0 ± 1.1b	14.5 ± 7.4b	53.0 ± 26.0a,b

[1]*Means in columns within each maturity group followed by different letters are significantly different, P = 0.05.*

Fuel Reduction

Table 3 shows weight and depth reductions of forest floor fuels from the three burns. Forest floor weight reductions reflect needle weight reductions because needles and humus make up at least 80% of the forest floor. In both groups, areas 2 and 3 fuel weight and depth reductions were statistically similar, in most cases, but both were significantly greater than reductions on area 1. This coincides with F and H layer moisture differences (table 2). A noted exception occurred in the open group, where total fuels and depth reductions in area 3 were not different from those in area 1.

Hough (1968) and Van Wagner (1972) developed forest floor reduction regressions, based on fuel moisture conditions for burning in southern and northeastern pine stands, respectively. Both regressions underestimated the fuel reduction observed in the study, although

Table 1.—Weather and fire behavior observations during three prescribed burns

Area	Temperature	Relative humidity	Windspeed[1]	Rate of spread	Flame length	Fireline intensity
	degrees Fahrenheit	*percent*	*miles per hour*	*feet per minute*	*feet*	*Btu per foot per second*
1	75-78	33-41	1-4, upslope	0.51	0.3-0.6	0.3-1.8
2	70-75	45-55	1-3, upslope	.45	.4- .8	.8-3.8
3	68-74	19-28	1-4, upslope	.54	.5-1.0	1.2-5.7

[1]*Measured at 4.5 feet above the ground.*

moisture values of specific layers were not strictly comparable. In northern Arizona, Davis et al. (1968) reported ponderosa pine duff reduction of 33% and 36%, with H layer moisture of 18% and 26%, respectively. These reductions were much less than those found in this study under similar conditions, but original loadings were only 40% to 70% of those reported here.

This situation, where lighter original loadings may lead to relatively lower fuel reduction, as suggested by Sweeney and Biswell (1961), was also interpreted from Gaines et al. (1958). In that study, 4-7 tons per acre of ponderosa pine fuels were reduced only 50%, with 9-12% fuel moistures, and warm, dry, ambient conditions. A more recent study, in ponderosa pine stands of northern Arizona, showed a 63% forest floor weight reduction, with surface fuels averaging 8-12% moisture, and the F and H layer averaging less than 20% moisture (Sackett 1980). These moisture conditions were comparable to those in area 2 of this study, which had a 74% forest floor reduction when open and closed groups were combined. Also, with the H layer at 28% moisture content, Sackett (1980) reported a 42% forest floor reduction, which is less than a 61% reduction under similar conditions of this study (area 3). Evening and night burning with low air temperatures and higher relative humidities in Sackett's study as opposed to mid-day burning in this study could explain the fuel reduction differences.

Percent reduction of larger fuel (>3 inches) is shown in table 4. High variability prevented valid statistical comparisons.

More of this fuel class was burned in the open groups, and more rotten material was consumed in both groups than sound material. Moisture contents of sampled logs were quite inconsistent, because of their variable physical characteristics and location within the stand, with regard to openings, drip zones, and canopy cover. The sample size of only two was not adequate for this variability. In contrast to consumption of smaller fuels, reduction of rotten, <3-inch fuels in the open groups appeared slightly greater in area 1. Area 2 sound fuels burned poorly in both open and closed groups, probably because much of them occurred as single logs. In the other areas, more logs were grouped, permitting heat transfer between them and more complete burning (Albini 1976). In addition, 7 hours after ignition, a light rain dampened the smoldering fires on area 2, further reducing total consumption. In general, most large fuels were at least charred, reducing their ignitability.

Table 4.—Percent weight reduction of >3 inch woody fuels ($n = 3$ plots per area)

Maturity group	Area	Sound	Rotten	Total
Open	1	64.8	74.7	72.6
	2	20.9	56.5	40.1
	3	67.2	54.5	57.6
Closed	1	38.5	23.8	31.1
	2	6.5	47.7	29.2
	3	39.9	43.2	42.6

Sackett (1980) also found inconsistent reduction of <3-inch fuels. Under fairly dry conditions, 99% of the rotten material burned, but only 14% of the sound material was lost. Under wetter conditions, relatively equal percentages (41% and 47%) of rotten and sound fuels were consumed.

The effects of the three burns on the stand are illustrated in table 5. The smallest trees were killed most easily, thereby increasing the average stand diameter. Greatest tree mortalities were associated with areas of greatest fuel reduction. In the open groups, basal areas decreased only slightly, because the larger trees were not affected by the fires. Basal areas were significantly changed in the closed groups because of the high mortality rate.

The ladder fuels, such as low-crowned seedlings and saplings, can permit an intense ground fire to move into the overstory crowns. The following percentages of seedlings and saplings, respectively, were killed: area 1, 57% and 16%; area 2, 96% and 54%; area 3, 84% and 43%. Even where trees were not killed, the previously low

Table 3.—Percent of forest floor weight and depth reduction with standard deviations ($n = 3$ plots per area)

Maturity group	Area	Total fuels	Forest floor ≤1 inch	Needles or humus	Forest floor depth
Open	1	46.2 ± 16.7a[1]	39.9 ± 12.9a	35.8 ± 13.6a	52.8 ± 6.5a
	2	74.8 ± 6.5b	78.7 ± 5.2b	77.0 ± 8.8b	80.5 ± 5.7b
	3	60.3 ± 9.9a,b	62.3 ± 11.2b	62.1 ± 12.2b	64.5 ± 6.8a
Closed	1	34.1 ± 10.5a	36.0 ± 9.0a	33.3 ± 12.8a	43.1 ± 6.0a
	2	53.9 ± 9.8b	67.4 ± 4.5b	67.4 ± 3.6b	74.6 ± 9.4b
	3	54.2 ± 8.4b	58.7 ± 5.9b	55.6 ± 9.8b	62.1 ± 9.1b

[1]*Means in columns followed by different letters are significantly different, P = 0.05.*

crowns were raised when scorched foliage fell. The crowns in the closed groups were approximately 5 feet above the forest floor before burning and were raised to about 8 feet in area 1 and 14 feet in areas 2 and 3. The removal of these aerial fuels, along with the ground fuels, reduced the crowning potential, just as Kilgore and Sando (1975) reported. However, the area should be reburned to remove the fire-created litter.

In general, the results of this study compare favorably to successful prescribed burning described by Weaver (1952) and Biswell et al. (1973). Fuel reduction was effective and the fires remained completely controllable. That burning, however, was conducted during cool, dry, fall conditions which occur infrequently in the Southwest.

Preliminary Burning Prescriptions

The L layer moisture contents during the three burns were similar within maturity groups, with the possible exception of area 1 of the closed groups (table 2). They all carried fire at about the same rate of spread. Differences in forest floor fuel consumption were related closely to H layer moisture differences. Therefore, by holding weather and L layer moisture to narrow ranges, a very preliminary prescription for fuel reduction was developed (table 6).

The air temperature and windspeed ranges have been expanded downwards and upwards, respectively, beyond those conditions encountered during these burns. These changes, based on experience, will broaden the prescription limits while influencing fuel reduction and fire behavior only slightly. The L layer moisture ranges could be expanded somewhat, especially in the open groups, but these would coincide with unfavorable changes in the closed groups. For example, if the open L layer had 9% or 10% moisture, the corresponding moisture in closed groups would be approaching the moisture of extinction for backing fires (12-14%).[3]

Control problems were minimal during these summer burns. In area 1, with moist F and H layer fuels, no problems were encountered as the low intensity fire backed slowly. Even with the drier fuel conditions in area 2, the backing fire was easily managed. Short strip head fires, used to straighten out fire fronts, burned more intensely and increased scorch heights. Heavy fuels ignited rapidly and burned fiercely for some time, causing individual or group crowning or severe scorching directly above. This normally occurred in dense sapling groups, where thinning may be beneficial. Surface fuels ignited more rapidly in area 3 because of low moisture contents. Again, individual or group crowning occurred infrequently, but created no control problems.

Fire danger and fuel reduction success of these prescriptions differ somewhat from those predicted by Allen et al. (1968). Figure 3 shows tentative prescription limits for burning low volume fuels in Southwest forest understory. Conditions encountered during the burning of areas 1, 2, and 3 are marked.

The prediction guide (Allen et al. 1968) shows greater fire danger when area 1 was burned than area 2. Actually, drier fuels in area 2 caused higher intensities. Also, according to Allen et al. (1968), area 3 was burned in the fire-danger-too-high-for-control range, but no problems were encountered with the slow-moving backing fires. These comparisons suggest that relative humidity and fuel stick moisture alone are not sufficient prescription parameters. This prediction guide is being reevaluated.

Table 6.—Preliminary burning prescriptions with expected fuel reductions (percent) for ponderosa pine stands in the Santa Catalina Mountains[1]

Maturity group	L layer moisture	H layer moisture	Forest floor reduction
Open	5-7	15-25	75-85
	5-7	30-40	55-65
	5-7	75-90	30-40
Closed	6-9	25-35	65-75
	6-9	50-60	50-60
	6-9	70-85	30-40

[1] *Weather conditions applicable for downslope, backing fires only. Air temperatures: 55-75° F. Relative humidities: 25-50%. Wind at 4.5 feet: upslope, 1-5 miles per hour.*

Table 5.—Changes in stand characteristics from three prescribed burns

Maturity group	Area	Average d.b.h.			Trees per acre			Basal area per acre		
		Before	After	Increase	Before	After	Decrease	Before	After	Decrease
		inches		percent			percent	square feet per acre		percent
Open	1	3.2	3.9	21.9	820	595	27.4	163	157	3.6
	2	5.6	9.9	76.8	490	195	60.2	191	187	2.1
	3	6.7	11.7	74.6	500	325	35.0	269	267	0.7
Closed	1	2.4	2.7	12.5	3,230	2,460	23.8	179	171	4.5
	2	2.4	3.6	50.0	3,885	1,750	55.0	191	143	25.3
	3	2.6	3.3	26.9	3,420	1,910	44.2	187	156	16.6

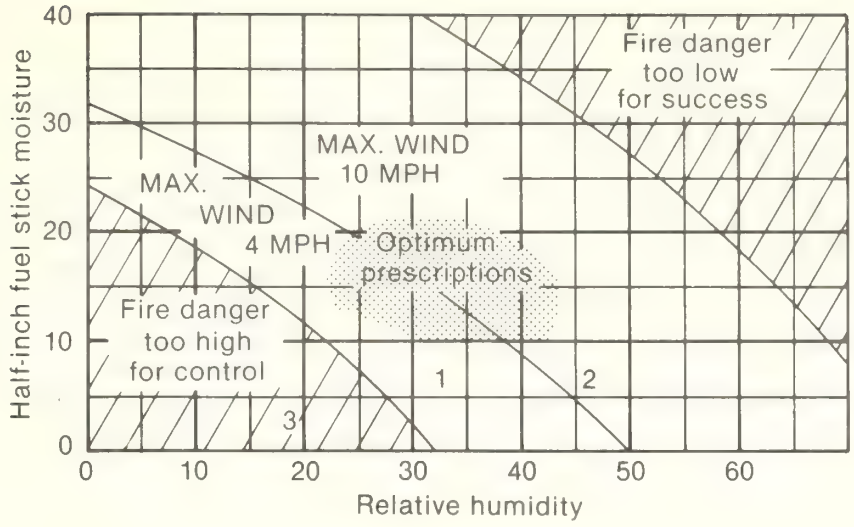


Figure 3.—Prediction guide for Southwest forest understory burning (Allen et al. 1968). Conditions during the three burns reported here are marked.

It should be emphasized that the execution of safe, effective prescribed burns under the stand, fuel, and weather conditions of this study depends on patient control of downslope backing fires. Much burning time will be required for initial fuel reductions with these creeping, deliberate fires, but strict adherence to this rule is necessary to maintain control.

Literature Cited

Albini, Frank A. 1976. Computer based models of wildland fires behavior: A user's manual. 68 p. U.S. Department of Agriculture, Forest Service. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Allen, Myron H., R. W. Berry, Dexter Gill, G. Lloyd Hayes, Paul S. Truesdell, Malcolm Zwolinski, and John M. Pierovich. 1968. Guide to prescribed fire in the Southwest. 58 p. Southwest Interagency Fire Council, Tucson, Ariz.

Biswell, Harold H., Harry R. Kallander, Roy Komarek, Richard J. Vogel, and Harold Weaver. 1973. Ponderosa fire management. Miscellaneous Publication 2. 49 p. Tall Timbers Research Station, Tallahassee, Fla.

Brown, James K. 1974. Handbook for inventorying downed woody fuels. USDA Forest Service General Technical Report INT-16, 24 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Byram, G. M. 1959. Combustion of forest fuels. p. 90. *In* Forest Fire: Control and use. Kenneth P. Davis, editor. McGraw-Hill Book Co., New York, N.Y.

Davis, James R., Peter F. Ffolliott, and Warren P. Clary. 1968. A fire prescription for consuming ponderosa pine duff. USDA Forest Service Research Note RM-115, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Gaines, Edward M., Harry R. Kallander, and Joe A. Wagner. 1958. Controlled burning in southwestern ponderosa pine: Results from the Blue Mountain plots, Fort Apache Indian Reservation. Journal of Forestry 56:323-327.

Hough, W. A. 1968. Fuel consumption and fire behavior of hazard reduction burns. USDA Forest Service Research Paper SE-36, 7 p. Southeastern Forest Experiment Station, Asheville, N.C.

Kilgore, Bruce M., and Rodney W. Sando. 1975. Crownfire potential in a sequoia forest after prescribed burning. Forest Science 21(1):83-87.

Sackett, Stephen S. 1979. Natural fuel loadings in ponderosa pine and mixed conifer forests of the southwest. USDA Forest Service Research Paper RM-213, 10 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Sackett, Stephen S. 1980. Reducing natural ponderosa pine fuels using prescribed fire: Two case studies. USDA Forest Service Research Note RM-392, 6 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Sweeney, James R., and Harold H. Biswell. 1961. Quantitative studies of the removal of litter and duff by fire under controlled conditions. Ecology 42(3):572-575.

Van Wagner, C. E. 1972. Duff consumption by fire in eastern pine stands. Canadian Journal of Forest Research 2:34-39.

Weaver, Harold. 1952. A preliminary report on prescribed burning in virgin ponderosa pine. Journal of Forestry 50:662-667.

Agriculture—CSU, Fort Collins

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains Southwest Great Plains

Research Note RM-403

May 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Acephate Residues in Second Year Cones of *Pinus sylvestris* L. Sprayed to Prevent Damage by *Dioryctria disclusa* Heinrich

Mary Ellen Dix, Charles E. Richmond, and James L. Van Deusen[1]

UNIVERSITY LIBRARY
JAN 11 1982
TECH. & AGR. DIV.

Residue analysis of homogenized cones and wash indicated that acephate (Orthene 75S)[2] and methamidophos were present in or on the cones for 10-15 days after spraying with acephate. Spray rates were 2 pounds per 100 gallons (2.36 g/l) and 4 pounds per 100 gallons of water (4.73 g/l).

Keywords: Acephate residues, methamidophos, Scotch pine, webbing coneworm, cone protection, systemic insecticides

Management Implications

The residues of acephate (O,S-dimethyl acetylphosphoramidothioate) and its metabolite, methamidophos (O,S-dimethyl phosphoramidothioate), present in and on Scotch pine (*Pinus sylvestris* L.) cones 10-15 days after spraying, should be sufficient to prevent damage by early instar larvae of the webbing coneworm (*Dioryctria disclusa* Heinrich). Even when very few *D. disclusa* were present, acephate applied at 2 pounds per 100 gallons of water apparently reduced feeding and tunneling damage to second year Scotch pine cones, while not reducing seed production per cone. However, because of the relatively low *D. disclusa* population during this test, additional tests must be conducted when populations are more abundant before test results would warrant a registration application for acephate to control *D. disclusa* on *P. sylvestris*.

[1]*Dix and VanDeusen are Research Entomologist and Research Forester, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station Research Work Unit at Bottineau in cooperation with North Dakota State University, Bottineau Branch. Station's headquarters is in Fort Collins in cooperation with Colorado State University. Richmond is Research Biologist, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.*

[2]*The use of trade, firm, or corporation names in the publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.*

Introduction

Scotch pine, a widely distributed and economically important tree in Europe and Asia (Little 1979), has been introduced into the United States for use in shelterbelts and plantations and as an ornamental. The USDA Forest Service is developing improved varieties of Scotch pine for use on the Great Plains in shelterbelts and as Christmas and ornamental trees.

Tree improvement research is particularly hampered when high value, control pollinated cone crops are lost or reduced by insect infestations, such as the webbing coneworm. The young larvae of this moth initially feed on the staminate cones until lack of food forces them to migrate to second year cones. Each larva may feed on as many as two Scotch pine cones, damaging portions or entire cones (Mattson 1976). Damaged cones may produce fewer seeds or abort before reaching maturity.

Acephate (Orthene 75S), a systemic insecticide which is toxic to a variety of forest insect pests (Brown and Eads 1975, Brown et al. 1978, Neisess et al. 1976, Brewer and O'Neal 1977, and Richmond et al. 1979), has both systemic and contact activity on some species of conifers (Richmond et al. 1978). This paper describes the insecticide residue levels found on the surface of intact cones and extracted from the homogenized tissue of cones sprayed with acephate.

Methods and Materials

Study Area

In 1963, the USDA Forest Service established a provenance test of Scotch pine on the Denbigh Experimental Forest in North Dakota as part of the search for species adapted to the northern Great Plains climate. By 1977 the trees were 23-28 feet (7.0-8.5 m) tall, about 6.0 inches (15.2 cm) d.b.h., with a 10- to 12-foot (3.0-2.7 m) crown diameter.

Insecticide Application

In 1977, crews sprayed with acephate nine plots containing at least three trees per plot. Selection was made without regard to seed source. The only requisite was that each candidate tree bore at least 30 first-year conelets. The young trees were just beginning to bear good seed crops, and production was variable among trees. To avoid cross contamination of insecticide treatments, plots were separated by at least three trees.

Each of the following treatments was applied to three plots selected at random:

(1) Control (not sprayed).
(2) 2 pounds acephate per 100 gallons of water (2.36 g/l).
(3) 4 pounds acephate per 100 gallons of water (4.73 g/l).

Crews sprayed all treated trees when the air was calm on May 6, 1977, approximately one week before anthesis. The entire crown of each noncontrol tree was sprayed to the point of runoff with a 50 pounds per square inch hydraulic sprayer. Personnel reached the tree crowns by means of a maneuverable bucket on a truck-mounted boom.

Residue Analysis

Treatments and controls were sampled for residue analysis on the day of spraying (day 0), and at 1, 5, 10, 17, and 30 days after spraying. Because of the high cost of residue analysis, only two of the three plots were used. Each sample contained 30 cones randomly selected from each treatment, or 5 cones from each tree. The 30 cones in each sample were packaged together and immediately refrigerated.

Each 30-cone sample was divided into 3 sets (10 cones per set), which were washed 3 times with 200 ml distilled water. The washes were extracted and analyzed to determine the amount of surface insecticide residue, expressed as micrograms per sample because the amount of residue represented a measurement of deposit on the surface of the cones. The amount of insecticide recovered from the water wash is a function of surface area, not cone weight, hence it cannot be expressed in parts per million. Following the surface wash, the whole cones were homogenized (ground up), extracted, and characterized by gas liquid chromotography (GLC), using previously established methods (Richmond et al. 1978, Richmond et al. 1979). Residues extracted from the whole cone homogenate were assumed to have penetrated directly into the cone and can be expressed in parts per million. The analytical procedures used for extraction and characterization of acephate also extract and detect methamidophos, a toxic metabolite. Each sample was analyzed three times and the content of acephate and methamidophos calculated as the average of the three GLC readings. Then the average proportions of acephate and methamidophos for the two replications were calculated. In addition, small quantities of both acephate and methamidophos were added to untreated cone tissue prior to washing and homogenizing to determine the percent recovery of the extraction method.

Cone Protection and Insecticide Phytotoxicity

A second sample of 30 cones randomly picked but equally distributed among the study trees was examined for *D. disclusa* larvae and their damage on day of spraying (day 0), and 1, 5, 10, 17, and 30 days after spraying. The presence of *D. disclusa* larvae or insect damage on the 30-cone sample was recorded. While examining the cones for larvae and damage, crews also examined the trees for unusual browning, needle drop, or unusual growth.

In July 1977, the remaining cones on each tree in each treatment were checked for insect damage. In September, the cones were collected. The number of seeds per cone was counted, and the percent sound seed per cone was calculated for each tree. Sound and empty seed were separated using a seed blower, with accuracy of separation checked by cutting open subsamples of seeds and by x-raying subsamples of seeds.

Treatments were compared using an analysis of variance and the Student Newman Keuls Test. Bartlett's test for homogenous variance was performed on all data (Steel and Torrie 1960, Sokal and Rohlf 1969).

Results and Discussion

Residue Analysis

The overall mean percent recovery of methamidophos in tissue to which methamidophos had been added was 75.1% (SD = 6.28), while that for acephate in the tissue to which acephate had been added was 80.8% (SD = 3.53). Because the amount of methamidophos in sprayed cones was never more than 0.61 p/m and decreased with time, that amount was added to the acephate concentration to give the total amount of insecticide recovered by date and treatment in micrograms per sample, or parts per million (figs. 1 and 2).

The concentration of acephate which will kill 50% of the test insects, or LC_{50}, for *D. disclusa* is unknown. However, the LC_{50} for sixth stage larvae of the western spruce budworm (*Choristoneura occidentalis* Freeman) is 7.7 p/m (Richmond et al. 1978). If we assume the LC_{50} dose for early stage *D. disclusa* larvae is similar to

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some states have restrictions on the use of certain pesticides. Check your state and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or state extension specialist to be sure the intended use is still registered.

Table 1.—*Dioryctria disclusa* damaged cones on Scotch pine trees in July

Treatment	Trees	Cones				
		Total checked	Crop per tree		Damaged[1]	
		number		*SD*	*percent*	*SD*
Control	9	1267	140.8	133.89	4.15 a	2.03
Acephate 2 pounds per 100 gallons water	10	798	79.8	60.99	0.67 b	1.99
Acephate 4 pounds per 100 gallons water	10	1760	176.0	75.65	0.66 b	2.12

[1]*Means followed by different letters vary significantly at the 5% level according to the Student Newman Keuls test. Bartlett's test for homogenous variance was not significant ($X^2 = 0.2$, $df = 2$).*

Table 2.—Effect of acephate on Scotch pine seed production

	Seed per cone		Sound seed per cone			
	Mean number	SD	Mean number	SD	Mean percent[1]	SD
Control	22.8	10.92	21.3	10.27	92.5 a	4.45
Acephate 2 pounds per 100 gallons water	21.9	8.37	19.8	7.47	90.1 a	4.18
Acephate 4 pounds per 100 gallons water	18.2	9.99	14.1	8.77	74.4 b	13.41

[1]*Means followed by different letters vary significantly at the 5% level according to the Student Newman Keuls test.*

Literature Cited

Brewer, J. W., and J. O'Neal. 1977. Early ground applications of acephate for control of the western spruce budworm (Lepidoptera: Tortricidae) on Douglas-fir. Canadian Entomologist 109:1153-1158.

Brown, L. R., and C.O. Eads. 1975. Nantucket pine tip moth in southern California: Identity and insecticidal control. Journal of Economic Entomology 68(3): 380-382.

Brown, L. R., C. O. Eads, C. E. Crisp, and M. Page. 1978. Control of a Jeffry pine needle miner by spraying and trunk implantation and resultant acephate residues. Journal of Economic Entomology 72:51-54.

DeBarr, Gary L., and Vicki H. Fedde. 1980. Contact toxicity of 17 insecticides to larvae of *Dioryctria amatella* (Lepidoptera: Pyralidae). Canadian Entomologist 112:521-523.

Little, Elbert L., Jr. 1979. Checklist of United States trees (native and naturalized). USDA Forest Service, Agriculture Handbook 541, 375 p. Washington, D.C.

Mattson, William J. 1976. Distribution of the cone insect, *Dioryctria disclusa* in red pine trees. USDA Forest Service Research Paper NC-136, 7 p. North Central Forest Experiment Station, St. Paul, Minn.

Neisess, J. G., P. Markin, and R. Schaefer. 1976. Field evaluations of acephate and dimilin against the Douglas-fir tussock moth. Journal of Economic Entomology 69(6):783-786.

Richmond, C. E., R. D. Averill, and C. E. Crisp. 1978. Protection of Douglas-fir foliage from western spruce budworm (Lepidoptera: Tortricidae) on Douglas-fir. Canadian Entomologist 109:1153-1158.

Richmond, C. E., C. E. Crisp. J. E. Larson, and G. R. Pieper. 1979. Simple method for assessing acephate and methamidophos residues in plant tissues. Bulletin of Environmental Contamination and Toxicology 22:512-516.

Sokal, Robert R., and F. James Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. 776 p. W. H. Freeman and Company, San Francisco, Calif.

Steel, Robert G. D., and James H. Torrie. 1960. Principles and procedures of statistics. 481 p. McGraw-Hill Book Co. Inc., New York, N.Y.

sixth stage budworm larvae, this lethal concentration of acepand methamidophos would have remained in the cones for about 14 days after spraying at both the 2-pound rate and the 4-pound rate (fig. 2). DeBarr and Fedde (1980) found that LC_{50} for first stage *Dioryctria amatella* (Hulst) larvae, a related species, is about 1 p/m for Guthion, 6.5 p/m for carbofuran, and 12 p/m for phosmet. Although the budworm and coneworm larvae are different instars and different families, an LC_{50} level of 7.7 p/m acephate for *D. disclusa* and *C. occidentalis* is comparable to the LC_{50} levels of these insecticides with *D. amatella*.

Detectable residue levels remained on the surface of the cones for 9-15 days following treatment (fig. 1). There was little difference between treatments, indicating that the 2 pounds a.i. per 100 gallons rate would be as effective as 4 pounds a.i. per 100 gallons (fig. 1 and 2). No significant acephate and methamidophos residues were detected beyond 15 days after application indicating that the tree had either metabolized the acephate or the acephate had broken down.

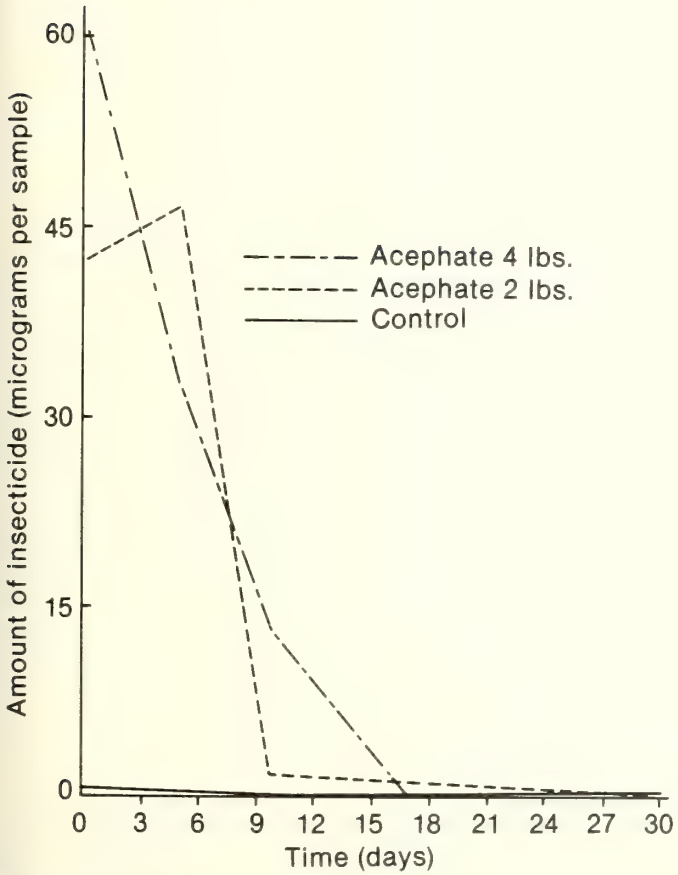


Figure 1.—Combined residues of acephate and methamidophos from water wash of cones of Scotch pine sprayed by ground application for suppression of webbing coneworm. Residues expressed as micrograms per sample, represent amount of insecticide deposited on the surface of the cones following treatment. The plotted line of values for the control trees cannot be distinguished from the abscissa.

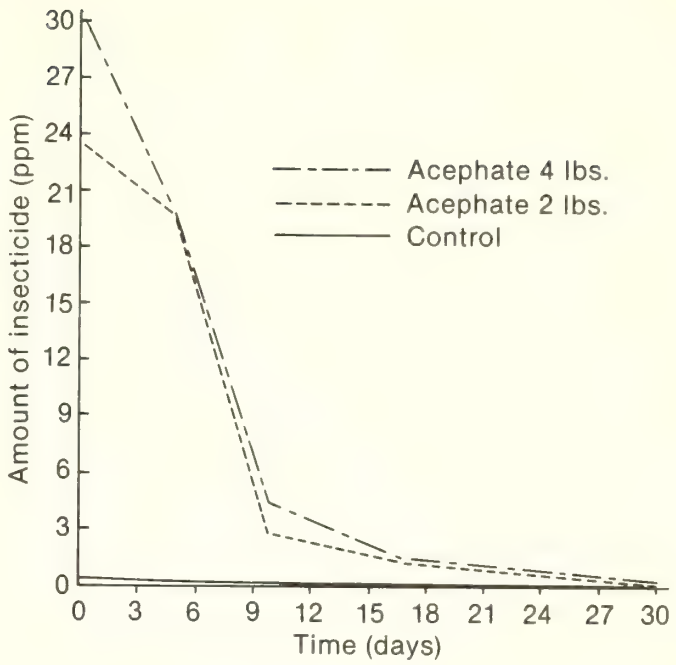


Figure 2.—Combined residues in parts per million of acephate and methamidophos from homogenized cones of Scotch pine sprayed by ground application for suppression of webbing coneworm. Residues represent amount of insecticide which penetrated into the cones. The plotted line of values for the control trees cannot be distinguished from the abscissa.

Cone Protection

The *D. disclusa* population in the study plot greatly declined between June of 1976 and June 1977, so the effect of acephate on larvae was almost impossible to obtain. No damaged cones were collected until the 30-day posttreatment sampling when four damaged cones were collected in the control sample. None of the treated cones in this sample was damaged. Several larvae were first observed on nontest trees in the plantation plot 12 days after spraying and these were in a late instar stage. Only a few larvae were observed on test and nontest trees at later dates.

Scotch pines in the control plots had significantly more cones on the entire tree with *D. disclusa* damage than did trees which received the acephate 2-pound and acephate 4-pound treatments (table 1). Although the treatments were randomly assigned to plots, the acephate 2-pound plots had fewer cones per tree, but this difference was not significant.

Phytotoxic Effects of Insecticides

No discoloration, unusual needle drop, or abnormal growth was observed on any of the trees sprayed with acephate. The number of seeds per cone did not vary significantly among treatments. The percentage of sound seed per cone decreased at the 4-pounds-per-100-gallons rate (table 2).

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-404

June 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Variation in Growth of Engelmann Spruce Seedlings Under Selected Temperature Environments

Wayne D. Shepperd[1]

CLEMSON UNIVERSITY LIBRARY
JAN 11 1982
SCI., TECH. & AGR. DIV.

Seedlings grown with soil temperatures kept higher than air temperatures in the daytime and with soil and air temperatures kept equal at night produced significantly longer and heavier roots than seedlings grown under conditions previously considered optimum (i.e., soil and air temperatures both higher at night than in the daytime).

Keywords: *Picea engelmannii*, tree physiology, containerized seedlings

Management Implications

This study has demonstrated that, under specific, controlled environments, growth of Engelmann spruce (*Picea engelmannii* Parry) seedlings does respond to relatively slight changes in air and soil temperatures. Seedlings grown for 14 weeks in a regime where daytime soil temperature was higher than air temperature produced slightly larger tops and significantly larger roots than seedlings grown under a regime in which air and soil temperature were not varied.

This study provides a possible means of increasing the growth rate of commercially produced, containerized Engelmann spruce planting stock by closely regulating root temperature. These techniques could be used in commercial greenhouse operations either to produce larger seedlings or to shorten the greenhouse production cycle.

Introduction

Engelmann spruce is a primary timber species in the central Rocky Mountains. While current silvicultural management is directed toward regenerating the species naturally, through even-aged shelterwood cutting methods (Alexander 1974), a substantial reforestation backlog exists in areas which were clearcut in the 1960's and early 1970's. Traditionally, Engelmann spruce has been artificially regenerated by planting nursery grown, bare-root stock. However, 3 years are needed to produce trees large enough for field planting. Under current economic conditions, this is becoming more expensive. Therefore, the production of containerized stock, in controlled environments, is becoming a viable alternative (Colby and Lewis 1973). Hellmers et al. (1970) studied the growth of Engelmann spruce under controlled environments, and found the temperature combination producing the greatest height growth and dry matter production was a diurnal variation of 19° C day temperature and 23° C night temperature. Because air and soil temperatures were the same, the role of soil temperature alone in increasing Engelmann spruce seedling growth was not evaluated.

The influences of soil temperature on growth of plants has long been established. Studies of coniferous tree species have shown that growth of redwood and ponderosa pine can be enhanced by maintaining soil temperatures equal to or greater than air temperatures (Hellmers 1963, Larson 1967), while optimum growth of white spruce requires soil temperatures to be slightly less than air temperature (Heninger and White 1974).

The effect of temperature on the growth of Engelmann spruce has not been investigated under conditions where soil temperatures have been controlled independently of air temperatures. Therefore, this study was made to determine the growth of Engelmann spruce seedlings under four combinations of day-night and air-soil temperatures.

[1]*Associate Silviculturist, Rocky Mountain Forest and Range Experiment Station; headquarters is in Fort Collins, in cooperation with Colorado State University.*

Methods

Because of limited facilities, treatment selection was restricted to several combinations of day and night air and soil temperatures, based on results of Hellmers et al. (1970).

Treatments chosen for comparison are shown in table 1.

Table 1.—Treatments used

Treatment	Temperature (° C)			
	Day		Night	
	Air	Soil	Air	Soil
1	19	19	23	23
2	19	23	19	23
3	19	19	19	23
4	19	23	23	23

Treatment 1, identical to Hellmers' et al. (1970) combination for best Engelmann spruce growth, served as an optimum bench mark to compare with effects of other treatments. Treatment 2 was an air-soil temperature differential with no diurnal variation in temperature; it was chosen to isolate any effect of air-soil temperature from day-night temperature. Treatments 3 and 4 provided additional contrasts of air-soil and day-night temperatures. These treatments were not in conflict with Hellmers' et al. earlier study, because a daytime air temperature regime was maintained which was less than or equal to the nighttime air temperature.

Seeds selected from a standard nursery seed lot were germinated in a germination cabinet then transferred to controlled environment growth chambers for the 14-week treatment period. Seedlings in all four treatments were grown in 1.25-liter pots, in a medium of coarse sand and perlite, and were watered daily with half-strength Hoaglands nutrient solution. A 16-hour photoperiod of 2,500 fc artificial light and a relative humidity of 80-90% were also standard. Because two germinator runs were required to supply enough seedlings, a randomized block design was used, with each treatment replicated twice. Each replication consisted of two pots containing 10 seedlings each.

Temperature was the only environmental parameter which was varied. Air temperature was kept within ±1° C in the growth chambers. An electrically heated, laboratory water bath was modified to provide the 23° C soil temperature treatment when needed.

After 14 weeks of growth, seedlings were carefully washed from the pots, total shoot height and shoot height above the cotyledons were measured, and the number of primary branches and lateral buds were recorded. Root length for each seedling was measured as a distance from the root collar to the tip of the longest root. Shoots and roots were then separated at the root collar, placed in separate weighing cans, and oven dried for 24 hours at 100° C before weighing. Oven dry weights were used to calculate root-shoot ratios. Pot averages were analyzed using a randomized block analysis of variance. A Tukey's Multiple Range Test was used to compare treatment means. These differences were significant at the 95th percentile ($P = 0.05$).

Results

The analysis revealed significant treatment differences for every variable measured (table 2). Treatments 1 and 4 produced seedlings with larger, heavier tops and larger total dry weights than seedlings grown under other treatments. No statistical difference was shown for root length and root dry weight between treatment 1 and treatments 2 and 3. However, root lengths and dry weights of treatment 4 seedlings were significantly greater than seedlings of the other three treatments.

Discussion and Conclusions

The significant improvement in root growth of seedlings in treatment 4 over those of the previously known optimum in treatment 1 suggest that the 23° C daytime soil temperature favored root development. While only root growth in treatment 4 was significantly greater than in treatment 1, the 23° C daytime soil temperature produced an overall larger seedling. This most likely had several physiological effects on growth of Engelmann spruce seedlings. The increase in soil temperature over the 19° C in treatment 1 probably caused a slight decrease in hydraulic resistance to absorption of water and nutrients by the roots, and an increase in root metabolic rate, which may have resulted in the increased root growth. Any increased uptake of water by roots would result in more favorable water potentials throughout the plant.

Apparently, soil temperatures higher than air temperatures benefit Engelmann spruce only during the day. The nighttime air-soil temperature differential in treatments 2 and 3 produced significantly less shoot growth than in treatments 1 and 4, which had no air-soil differential at night.

Some variation in growth was apparent among seedlings within each treatment (fig. 1). Because all environmental parameters were carefully controlled in this study and the variation was noticeable even among seedlings growing in the same pot within a treatment, it would seem that genetic diversity is responsible. Under current conditions, it is not economically practical to raise Engelmann spruce seedlings which will have to be culled at the end of an expensive greenhouse program.

Additional research by geneticists, silviculturists, and physiologists is needed to determine whether selection of seed from superior seed sources will eliminate or reduce this variation in growth under controlled environments, and whether seedlings, which grow best under optimum conditions in the greenhouse, will survive best when planted in the field.

Table 2.—Average Engelmann spruce seedling production after 14 weeks of growth[1]

Treatment		Temperature regime		Total shoot height	Shoot height above cotyledons	Length of roots	Number of primary branches	Shoot weight	Root weight	Total seedling weight	Root/shoot ratio
		Day	Night								
		° C		millimeters				milligrams (oven dry)			
1	Air	19	23	53.0_a	41.7_a	172.9_b	3.9_a	118.6_a	50.5_b	169.1_a	0.44_b
	Soil	19	23								
2	Air	19	19	31.3_b	20.0_b	155.4_b	2.1_b	69.2_b	49.4_b	118.6_b	0.89_a
	Soil	23	23								
3	Air	19	19	37.0_b	25.5_b	170.8_b	2.0_b	79.2_b	48.0_b	127.2_b	0.75_{ac}
	Soil	19	23								
4	Air	19	23	57.4_a	45.3_a	210.0_a	4.6_a	120.3_a	67.2_a	187.6_a	0.59_{bc}
	Soil	23	23								

[1]*Values within each variable having identical letters are statistically homogeneous at the 95th percentile (Tukey's Test).*

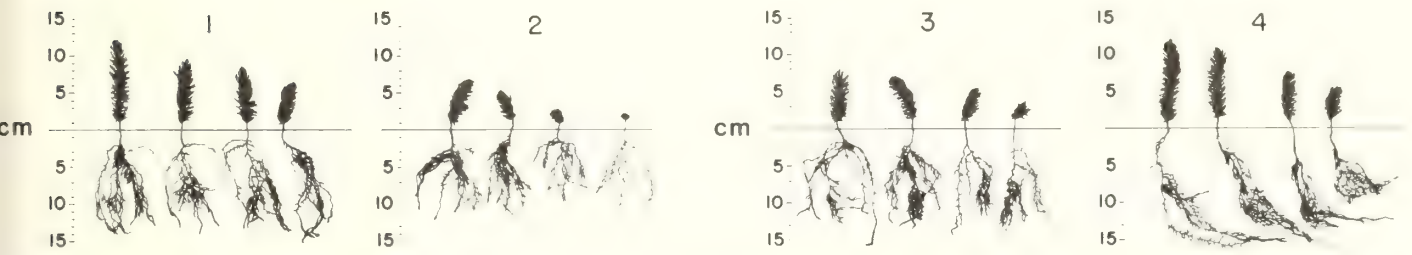


Figure 1.—Comparison of top and root development of seedlings from each treatment. The large variation in seedling size within each treatment is quite apparent, as are the longer roots of treatment 4 seedlings.

Literature Cited

Alexander, Robert R. 1974. Silviculture of subalpine forests in the central and southern Rocky Mountains: The status of our knowledge. USDA Forest Service Research Paper RM-121, 88 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Colby, Marilyn K., and Gordon D. Lewis. 1973. Economics of containerized conifer seedlings. USDA Forest Service Research Paper RM-108, 7 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Hellmers, Henry. 1963. Effects of soil and air temperatures on growth of redwood seedlings. Botanical Gazette 124(3):172-177.

Hellmers, H., M. K. Genthke, and F. Ronco. 1970. Temperature affects growth and development of Engelmann spruce. Forest Science 16(4):447-452.

Heninger, R. L., and White, D. P. 1974. Tree seedling growth at different soil temperatures. Forest Science 20(4):363-367.

Larson, M. M. 1967. Effect of temperature on initial development of ponderosa pine seedlings from three sources. Forest Science 13(3):286-294.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Mountains Southwest Plains

Research Note RM-405

June 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Prescribed Burning to Increase Mortality of Pandora Moth Pupae

CLEMSON UNIVERSITY LIBRARY
JAN 11 1982
SCI., TECH. & AGR. DIV.

J. M. Schmid,[1] L. Thomas,[2] and T. J. Rogers[3]

Prescribed burning of three different locations did not consistently cause satisfactory mortality to pandora moth pupae. It should be used only when the burning simultaneously achieves other objectives. Litter depth and distribution are important in uniformly heating and burning the proposed area.

Keywords: Pandora moth, *Coloradia pandora*, prescribed burning, fire effects

Few studies have investigated the use of fire to increase mortality of forest insects (Komarek 1970). Most economically damaging insects in western forests live on or in the tree where they would not be susceptible to fire unless the forests were severely burned. The pandora moth, *Coloradia pandora* Blake (Lepidoptera: Saturniidae), is an exception, because the larvae pupate in the soil and remain there from July of one year until the following July. Thus, they are susceptible to spring and fall prescribed burning under certain stand conditions. Prescribed burning has not been used to control the pandora moth, although Furniss and Carolin (1977) reported the Mono Indians used fire to cause the larvae to drop to the ground. This may have been an erroneous interpretation of Patterson (1929), who indicated the Indians used fire to dry larvae for food but not to increase their mortality.

This study was conducted to determine the effect of early summer prescribed burns on pupal survival, in stands of mature ponderosa pine, *Pinus ponderosa* Douglas ex Lawson.

[1]*Entomologist, Rocky Mountain Forest and Range Experiment Station. Headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2]*Fire Control Officer, Kaibab National Forest, Fredonia, Ariz.*

[3]*Entomologist, USDA Forest Service, Southwestern Region, Forest Pest Management, Albuquerque, N. Mex.*

Study Area

In 1979, a pandora moth infestation was detected on the Kaibab National Forest, near Jacob Lake, Arizona. Larval densities were high enough to cause nearly complete defoliation of mature ponderosa pine in some parts of the infested area. The larvae pupated in the litter and soil, in June and July 1979. Pupal densities exceeded 10 per square foot in preliminary samples taken from around the bases of trees.

Three potential, prescribed burning locations (A, B, C) were selected in early June 1980 (fig. 1). Physical characteristics of each are listed in table A-1. Basal areas for the three locations ranged from 125 to 150 square feet in 1973; the basal area was concentrated in large (16- to 19-inch) and oversize ($\geq$20-inch) sawtimber. Harvesting of the overmature, poor risk and form trees was begun in 1975 and completed in 1979. Locations A, B, and C were thinned to basal areas of 80-100, 100-110, and 80 square feet. All three locations were understocked with seedlings and saplings. They were chosen essentially without seedlings and saplings to reduce the possibility of a conflagration. Litter depth varied; it was greatest around tree bases and thinnest in openings between tree crowns. Although the litter was sparse in spots, litter conditions were thought to be representative of mature ponderosa pine stands on the north rim of the Kaibab plateau.

Methods

On June 24-25, 1980, the three locations were sampled to determine the pre-burn pupal densities. To disperse sampling throughout locations, four parallel compass lines were run across each location, and square foot plots were established at prescribed distances along each line. The distance between adjacent compass lines and plots along each line varied, depending on the size of the area. As each plot was established, another square foot plot was taken at the base of the closest tree 5 inches or more in diameter. Samples were taken near the tree bases, because pupae were thought to be concentrated there. Thus, plots on compass lines, unless they happened to fall near the base of a tree, would not reflect these concentrations. A total of 38, 28, and 24 line and tree plots were taken in locations A, B, and C, respectively.

The pupae in each plot were removed from the litter and first few inches of soil and were placed in petri dishes. Each dish was labelled as to area, transect line, and plot number. The dishes were transported to the laboratory in Fort Collins, where they were kept at room temperature. Adults eventually emerged, were counted, and the numbers were compared to postburn counts.

During the night of June 25, 1980, location C was burned with a backing fire (see table A-1 for fuel conditions). A backing fire burns against the wind and, thus, spreads more slowly than a fire burning with the wind. Because the fire danger was extreme at that time, burning of locations A and B was postponed. In the evening of July 14, 1980, locations A and B were burned with backing fires.

The morning after each fire, pupae were collected from plots along transect lines and the tree bases, according to the design used for the preburn samples, except that transect lines were offset 33 feet from the original lines to prevent sampling from the same location. Pupae from the post-treatment samples were placed in petri dishes, transported to the laboratory in Fort Collins, where they also were kept at room temperatures. Adults emerged in the dishes. In late August 1980, pupae from which adults had not emerged were dissected to determine if significant numbers of pupae had matured but failed to emerge.

Mean numbers of adults emerging from the preburn and postburn samples for each location were compared.

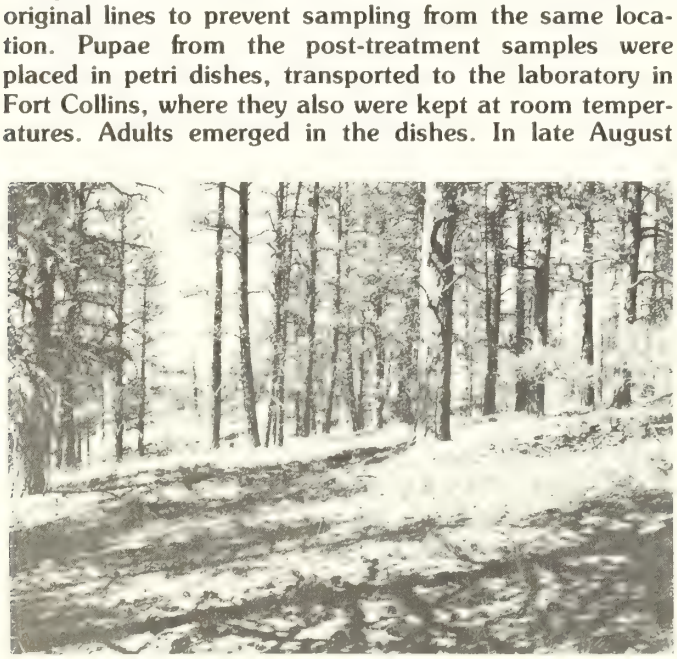


Figure 1.—Stand conditions on location A.

Results and Discussion

The mean density of emerging adults changed at all three locations (table 1). Locations A and B showed decreasing numbers of emerging adults between the preburn and postburn samples. Survival of pupae at tree bases decreased more than along transects. Location C showed an increase in the postburn densities of emerging adults along transect lines but a decrease in the densities at tree bases. These results reflect extremely variable pupal densities and the effects of the fire. While mean pupal densities averaged about 3 pupae per square foot in preburn and postburn samples, densities per square foot ranged from 0 to 32 pupae. This wide range suggests additional sampling may have increased the precision of the estimated densities and more clearly defined the effects of the burning. In addition, many pupae in both samples failed to develop and/or emerge, indicating inadequate rearing techniques or pupal mortality unrelated to the burning. However, despite these deficiencies, the percent changes (table 1) still reflect the efficiency of the prescribed burning under the existing stand conditions.

The fires generally caused higher mortality in areas with substantial depths of litter, such as the area within 3 to 6 feet of the base of a tree. Near and outside the dripline of the tree crowns, where the litter depth was less than 1 inch or nonexistent, the burning caused little or no pupal mortality. Because pupal densities 10 feet from the base of the tree were not different from those immediately adjacent to the base[4] and are probably just as high outside the dripline of the crown (contrary to prior belief), the negligible pupal mortality in these unburned and lightly burned areas decreased overall mortality and the efficiency of the burning. Thus, the overall mortality for each location attributable to the prescribed burning is somewhere between mortality near the tree bases and mortality in areas with sparse litter depth.

The pandora moth population in the three areas probably was not reduced enough by the prescribed burning to limit the 1981 defoliation to the light category. Using the presented data, subsequent abundance of adults can be approximated and defoliation estimated. Assuming the density of the pupae was 3 per square foot, then about 130,000 were present on each acre. If 50% of the pupae produced moths, 62,500 moths would fly. However, if a prescribed burn killed 60% of the viable pupae (the average of the negative percent changes in table 1), only 25,000 adults would emerge. More than half of the emerging moths would be females;[4] therefore, the larvae hatching from the egg masses of the 13,000+ females would be able to cause at least moderate defoliation.

[4]*Schmid, J. M., Unpublished data on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

Conclusions

Prescribed burning of stands where litter depth is interrupted and sparse in substantial portions of the area will not yield the moth population reductions normally desired from a control technique. If substantial litter is uniformly distributed throughout the stand and burning conditions are satisfactory, then prescribed burning becomes a more valuable control technique. If other objectives, such as fuel reduction or wildlife habitat management, can be achieved with the same fire used for pandora moth reduction, then the value of the prescribed burning is enhanced, even though it may not attain the desired pupal mortality.

The use of fire should not be completely dismissed because these results are not completely acceptable. Fall burning to increase pupal mortality, spring burning to effect larval mortality when the larvae are feeding, and spring burning when the larvae are leaving the trees to pupate are alternatives which should be tested. Larval and pupal population levels also should be measured periodically in the recently burned areas to determine if the fire decreases survival of later generations.

Literature Cited

Furniss, R. L., and V. M. Carolin. 1977. Western Forest Insects. U.S. Department of Agriculture, For. Serv., Misc. Pub. 1339, 654 p. Washington, D.C.

Komarek, E. V., Sr. 1970. Insect control—Fire for habitat management. p. 157-171. *In* Tall Timbers Conference on Ecological Animal Control by Habitat Management. No. 2. Tall Timbers Research Station, Tallahassee, Fla.

Patterson, J. E. 1929. The pandora moth, a periodic pest of western pine forests. U.S. Department of Agriculture, Tech. Bull. 137, 20 p. Washington, D.C.

Table 1.—Mean number of collected pupae and percent of emerging adults from preburn and postburn samples, on transect lines and near the bases of trees

Location	Collected pupae				Emerging adults		% change caused by treatment
	Preburn		Postburn		Preburn	Postburn	
	$\bar{X}$	*SD*	$\bar{X}$	*SD*	%	%	
Transects							
A	2.8	4.2	3.3	4.2	52	40	− 23
B	3.7	4.2	2.7	6.5	55	22	− 60
C	3.6	3.2	5.9	9.4	38	54	+ 142
Tree Bases							
A	3.4	4.8	2.7	4.1	50	27	− 46
B	3.8	4.5	1.3	1.5	37	0	− 100
C	3.2	3.2	1.2	1.6	58	20	− 66

Table A-1.—Summary of physical, meteorological, and fuel conditions for the three burn locations

Condition	Location		
	A	B	C
Hours burned	2050-0230	1900-2245	2130-0100
Temperatures (° F)	54-62	54-68	49-57
Relative humidity (percent)	18-29	22-35	27-34
Wind speed/direction	1-7, S-W	1-4, S/SW	Calm-2, S/SE
Slope (percent)	0-30	5	0-5
Aspect	West	North	Ridgetop
Elevation (feet)	7,800	7,800	8,000
Acreage	2	0.5	0.75
Fuels	Ponderosa pine duff, needles and light slash		
Loading (tons/acre)	5	4	4
Available (tons/acre)	4	3	2-3
Last precipitation (days since)	6 (0.05)	6 (0.05)	30 +
Fuel sticks (10-hour)	4	4	3-4

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-406

June 1981

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Overcoming Temperature-dependent Dormancy of Southwestern Ponderosa Pine Seed

CLEMSON UNIVERSITY LIBRARY
JAN 11 1982
SCI., TECH. & AGR. DIV.

L. J. Heidmann[1]

Germination of seeds *Pinus ponderosa* var. *scopulorum* is temperature-dependent. A laboratory experiment under fluctuating warm (16 hours at 24-27° C) and cold (8 hours at 3-4° C) temperatures showed that seeds given 48-hour aerated soaks of gibberellic acid (GA_3), thiamin, or nine other materials, including water, germinated faster than controls.

Keywords: Ponderosa pine, seed germination, dormancy

Management Implications

Planting is the surest method of regenerating ponderosa pine in the Southwest, but it is very expensive. Natural regeneration is much less costly but is limited to sedimentary soils. On soils of volcanic origin, first-year seedlings are quite small because of late germination and a short growing season. These small trees are highly susceptible to frost heaving and drought during the fall and winter. The potential for direct seeding exists on thouands of acres of volcanic soils in the Southwest if seeds can be stimulated to produce a larger tree, better able to withstand the rigors of frost heaving and drought. In addition, rapid germination would likely mean that much less seed would be required than formerly used.

Germination of southwestern ponderosa pine seed is temperature-dependent (Pearson 1950, Larson 1961). Seeds will germinate in a few days under optimum temperatures (20-25° C) without pretreatment. Germination is slowed considerably, however, under the fluctuating temperatures of the southwestern United States, where the diurnal range in summer is commonly 4-27° C. Germination in the field does not begin until midsummer when minimum soil temperatures reach 13° C (Larson 1961). A summer rainy season begins around July first, with germination following in mid-July to early August. There are only 30-50 days after germination for the seedling to become established before the onset of freezing nighttime temperatures in late August or early September. The size of seedling tops and roots is important in determining if the young tree will be able to withstand the drought and frost heaving of the first fall and winter (Schubert et. al. 1970, Heidmann 1976). Because the growing season is short and seedling size is vital to initial survival, any measures which will speed up germination are important. In addition, seeds which germinate rapidly are exposed to predation by seed eating rodents for a shorter period of time.

Although seeds of many coniferous species require moist stratification or some other pretreatment for germination (Pharis and Kuo 1977, U.S. Department of Agriculture 1974), southwestern ponderosa pine does not. Seeds will germinate rapidly in a germinator without pretreatment. Aerated soaking in water or gibberellic acid (GA_3)[2] will produce 50% germination in a few days at 20-25° C.[3] Thus, southwestern ponderosa pine seeds germinate rapidly at optimum temperatures. In the field, however, low night temperatures hinder germination.

Many means of hastening germination of conifer seeds have been tried with varying degrees of success (Lavender et al. 1964, McLemore 1971, Riffle and Springfield 1968, Trappe 1961, Biswas et al. 1972, Hall and Galsky 1973, McBride and Dickson 1972, Allen 1960, Barnett 1971). Because most of these experiments have been

[1]*Principal silviculturist, Rocky Mountain Forest and Range Experiment Station, Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2]*Abbreviations used: GA_3: gibberellic acid; NAD: nicotinamide adenine dinucleotide; ADP: adenosine-5-diphosphate; CGMP: guanosine-3',5'-cyclic monophosphate; CAMP: adenosine-3',5'-cyclic monophosphate; ATP: adenosine-5'-triphosphate; BA: N6-benzyladenine; ABA: abscisic acid.*

[3]*Data collected by L. J. Heidmann, on file at Research Work Unit, Flagstaff, Ariz., 1981.*

conducted in germinators or greenhouses at optimum temperatures, research is still needed to determine how to stimulate germination at field temperatures. For southwestern ponderosa pine, aerating seeds in gibberellic acid (GA_3) gave 50% germination in 5 days in fluctuating warm and cold temperatures, compared to 7 days for aeration in distilled water.[3] This reports a study to screen various compounds for their ability to stimulate germination of southwestern ponderosa pine seeds in a fluctuating warm and cool environment. Successful procedures would ultimately be applied to seeds used in field sowing.

The Study

The study, which was begun in 1977, tested several compounds reported in the literature to hasten seed germination (table 1). Southwestern ponderosa pine (*Pinus ponderosa* var. *scopulorum*) seeds were collected on the Apache-Sitgreaves National Forest (elevation 2150 m) in 1971. After extraction, the seeds were soaked in water for 24 hours to separate sound from hollow seeds. Seeds were then dried at air temperature to below 10% moisture content and stored in plastic bags at −11° C. Seeds used in the experiment had a moisture content of 6.3% and were soaked in a 30% solution of hydrogen peroxide (H_2O_2) for 20 minutes to sterilize the seed coats (Trappe 1961). Treatments, (table 1) were applied by aerating the seeds in 250 ml of solution for 48 hours at room temperature (20-24° C). Solutions of GA_3 were prepared by dissolving the material in 2 ml of ethanol and diluting to volume with distilled water. N6-benzyladenine (BA) was dissolved in 0.1 M HCl and diluted. All other compounds were dissolved in distilled water and diluted to volume. After treatment, seeds were removed from the solutions, rinsed with distilled water, and blotted dry on paper towels. Seeds were then placed in Petri dishes on Whatman number 5 filter paper which had been pre-wetted with 1 cc of distilled water. The experiment consisted of 3 randomized blocks of 26 treatments, each containing 50 seeds. Each replication was placed on a separate tray and then put into a refrigerator maintained at a temperature of 3-4° C. After 8 hours in the refrigerator the trays were removed and placed in a seed germinator for 16 hours under subdued light at a temperature which varied from 24° to 27° C. This procedure, which was repeated every day until conclusion of the study, was meant to simulate roughly the conditions encountered in the field. Each morning after onset of germination,

Table 1.—Effects of different treatments on germination of seeds of southwestern ponderosa pine

Treatments	Concentration	Days to 50% germination	Germination value	Total number of seeds germinating
GA_3	1.0 mM	6.7 a[1]	27.32	125
GA_3	0.1 mM	6.7 a	29.33	129
Thiamine	1.0 mM	6.0 a 7a	30.71	130
Thiamine	0.1 mM	6.7 a	26.70	118
Cytochrome C	10 μM	7.0 ab	24.61	122
NAD	1.0 mM	7.0 ab	24.96	123
ADP	1.0 mM	7.0 ab	28.35	128
CGMP	0.1 mM	7.0 ab	25.88	126
Aeration in distilled water		7.3 ab	24.15	122
CAMP	0.1 mM	7.3 ab	25.74	121
NAD	0.1 mM	7.3 ab	20.33	121
ATP	0.1 mM	7.7 ab	23.20	121
Adenine	0.1 mM	7.7 ab	23.13	119
Tryptophan	1.0 mM	7.7 ab	25.92	130
Cytochrome C	1.0 μM	8.0 abc	22.20	123
Adenine	1.0 mM	8.0 abc	20.14	114
Thiourea	0.1 mM	8.0 abc	17.88	103
CAMP	1.0 mM	8.3 abc	19.67	114
ATP	1.0 mM	8.7 abc	18.93	111
Tryptophan	0.1 mM	8.7 abc	21.87	121
CGMP	10 μM	8.7 abc	20.91	118
ADP	0.1 mM	9.3 abc	17.76	110
Thiourea	1.0 mM	9.3 abc	19.31	111
BA	0.1 mM	9.7 bc	15.15	99
Control		10.3 c	21.01	129

[1] *Treatments followed by the same letter are not significantly different (P = 0.05).*

seeds which had a radicle of 3 mm or longer were recorded as germinated and discarded. Filter paper was moistened daily as needed. The experiment was terminated at the end of 26 days. Days to 50% germination, total germination, and germination values (Czabator 1962) were analyzed by analysis of variance. The germination value (GV) is calculated as mean daily germination (number of full seed germinating at the end of the test divided by days to end of test) times the peak value (cumulative peak germination percent divided by days to peak.)

Results and Discussion

Southwestern ponderosa pine seeds aerated in several solutions germinated significantly faster than controls ($P = 0.05$) (table 1). Seeds treated with 1.0 mM and 0.1 mM solutions of GA_3 and thiamin reached 50% germination in 6.67 days compared to 10.3 days for the control. This was not significantly better, however, than several other treatments, including aeration in water, which took 7.3 days for half of the seeds to germinate (table 1). There were no differences in germination value or in total numbers of seeds germinating (table 1). The analysis was originally run for all 26 treatments, but treatment with BA at 1.0 mM significantly repressed germination ($P = 0.01$) and was omitted from further analysis.

It is not possible to pinpoint the cause of temperature-dependent dormancy of southwestern ponderosa pine on the basis of this experiment. There are some indications, however, of the mechanisms. Khan (1975) states that GA, cytokinin, and ABA play primary, permissive, and preventive roles in germination of seeds. Cytokinins oppose the actions of inhibitors but have little activity by themselves. Thus, germination will occur in the presence of ABA if cytokinin and GA are present, and in the absence of ABA if GA is present. Because germination in southwestern ponderosa pine seeds is rapid at temperatures over 20° C, we can assume that GA is present at these temperatures. ABA may also be present, in which case cytokinin is necessary for germination. As temperatures drop, the hormonal balance may change (Khan 1975). It is, therefore, possible that at low temperatures GA levels drop, while levels of cytokinin and ABA either rise or stay the same. The presence of both at low temperatures is indicated by the failure of BA to accelerate germination and the success of GA_3.

It has been suggested that moving water removes inhibitors from the seeds which allows germination to proceed.[4] It seems likely, however, that if inhibitors are leached from the seeds by moving water, cytokinins and GA would be also. A more likely explanation, because seeds aerated in water also germinated significantly faster than the control, is that oxygen plays a role in triggering germination.

Another possibility is that dormancy may be related to the amount of moisture imbibed by the seeds. Sukhorosova (1966), cited by Ovcharov (1969), found temperature differences to be extremely important in germination of maize seeds. Under favorable temperature, seeds began to germinate even though they had absorbed only half of the required moisture. When temperatures were low, germination did not begin until swelling of the seed was complete. In the laboratory, southwestern ponderosa pine seeds germinate readily on barely moistened filter paper in a few days, but in the field germination may be delayed until two or three weeks after the first rains in early July. Summer rains in Arizona during July and August are usually sporadic and of short duration and intensity. Because the minimum temperature at night drops to a few degrees above freezing, it may be that the seeds need to imbibe the maximum amount of moisture before germination can begin. This might take several showers. Moisture alone, however, does not appear to be the controlling factor, since soaking seeds of southwestern ponderosa pine in water without aeration depressed germination (Larson and Schubert 1969).

If thiamin stimulates seed germination, its role is not clear. Thiamin is known to function as a coenzyme and as such may enhance the activity of other compounds in the metabolic pathway.

In order to determine if GA_3, thiamin, and other substances act independently of oxygen in stimulating germination of southwestern ponderosa pine seeds, additional studies of a more sensitive nature should be conducted. These experiments should involve the use of carriers such as acetone so that materials can be introduced into the seed quickly, thus, eliminating the need for aeration (U.S. Department of Agriculture 1975, Tao and Khan 1974). It would also be beneficial to conduct experiments to identify promoters and inhibitors which may be present in seeds at both high and low temperatures.

[4] *Personal correspondence with Lavender, 1979.*

Literature Cited

Allen, G. S. 1960. Factors affecting the viability and germination behavior of coniferous seed. IV. Stratification period and incubation temperature. *Pseudotsuga menziesii* (mirb.) Franco. Forestry Chronicle 36(1):18-29.

Barnett, J. P. 1971. Aerated water soaks stimulate germination of southern pine seeds. USDA Forest Service Research Paper SO-67, 9 p. Southern Forest Experiment Station, New Orleans, La.

Biswas, P. K., P. F. Bonamy, and K. G. Paul. 1972. Germination promotion of loblolly pine and baldcypress seeds by stratification and chemical treatments. Physiologia Plantarum 27:71-76.

Czabator, Felix J. 1962. Germination Value: An index combining speed and completeness of pine seed germination. Forest Science 8(4):386-396.

Hall, Kathleen, and Alan G. Galsky. 1973. The action of cyclic-AMP on GA_3 controlled responses. IV. Characteristics of the promotion of seed germination in *Lactuca sative* variety "Spartan Lake" by gibberellic acid and cyclic 3,5′-adenosine monophosphate. Plant and Cell Physiology 14:565-571.

Heidmann, L. J. 1976. Frost heaving of tree seedlings: A literature review of causes and possible control. USDA Forest Service General Technical Report RM-21, 10 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Khan, Anwar A. 1975. Primary, preventive and permissive roles of hormones in plant systems. Botanical Review 41:4,391-420.

Larson, M. M. 1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. USDA Forest Service Research Note 66, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Larson, M. M., and Gilbert H. Schubert. 1969. Effect of osmotic water stress on germination and initial development of ponderosa pine seedlings. Forest Science 15(1):30-36.

Lavender, Denis P., and George H. Atherton. 1964. Sonic treatment of Douglas-fir and ponderosa pine seeds and seedlings. Research Note 48, 16 p. Forest Research Laboratory, Oregon State University, Corvallis, Oreg.

McBride, Joe R., and Richard Dickson. 1972. Gibberellic, citric acids and stratification enhance white ash germination. Tree Planter's Notes 23(2):1-2.

McLemore, B. B. 1971. Light requirements for germination of loblolly pine seeds. Forest Science 17:285-286.

Ovcharov, K. E. 1969. Fiziologicheskie oznovy vskhozhesti semyan (Physiological basis of seed germination). Nauka, Moscow, English translation Amerind Publishing Company, PVT., Limited, New Delhi, India, 1977, 315 p.

Pearson, G. A. 1950. Management of ponderosa pine in the Southwest. U. S. Department of Agriculture Monograph 6, 218 p. Washington, D.C.

Pharis, R. P., and C. G. Kuo. 1977. Physiology of gibberellins in conifers. Canadian Journal of Forest Research 7(2):299-325.

Riffle, J. W., and H. W. Springfield. 1968. Hydrogen peroxide increases germination and reduces microflora on seed of several southwestern woody species. Forest Science 14(1):96-101.

Schubert, G. H., L. J. Heidmann, and M. M. Larson. 1970. Artificial reforestation practices for the Southwest. U. S. Department of Agriculture Handbook 370, 25 p. Washington, D.C.

Tao, Kar-Ling, and Anwar A. Khan. 1974. Penetration of dry seeds with chemicals applied in acetone. Plant Physiology 54:956-958.

Trappe, James M. 1961. Strong hydrogen peroxide for sterilizing coats of tree seed and stimulating germination. Journal of Forestry 59(11):828-829.

U. S. Department of Agriculture, Forest Service. 1974. Seeds of woody plants in the United States. Agriculture Handbook 450, 883 p. Washington, D.C.

U. S. Department of Agriculture, Science and Education Administration. 1975. Impregnating seeds with chemicals. Agricultural Research, September, p. 5. Washington, D.C.

Rocky Mountains | Southwest | Great Plains

Research Note RM-407

June 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

SON UNIVERSITY LIBRARY
JAN 11 1982
TECH. & AGR. DIV.

Regeneration on Aspen Clearcuts in Northwestern Colorado

Glenn L. Crouch[1]

Clearcutting mature aspen, on 5-acre blocks, resulted in 18,000 sprouts per acre, and nearly full stocking of half-milacre plots after one growing season. Two years later, sprouts averaged about 8,000 per acre, and mean height of the tallest stem was 4.4 feet. Further normal declines in numbers of sprouts are expected but losses may be accelerated by trampling and browsing.

Keywords: *Populus tremuloides*, clearcutting, regeneration, animal damage

Quaking aspen (*Populus tremuloides* Michx.) is the most abundant deciduous tree in the central Rocky Mountains. Aspen dominated plant communities comprise more than 4 million acres of commercial forest land in the Rockies, with almost 2.3 million acres in Colorado (Green and Setzer 1974). Much additional acreage is occupied by noncommercial stands of aspen; the tree also commonly occurs in mixtures with various conifer species (Baker 1925).

In addition to wood products, aspen provides habitat for many wild birds and mammals and may be essential for some species (Armstrong 1977, Flack 1976, Gruell and Loope 1974, Reynolds 1969). Aspen forests also produce much forage, offer shelter for domestic livestock, and are major contributors to the pleasing appearance of vegetation mosaics so prized in the Rocky Mountain states.

Aspen usually reproduces vegetatively by sprouting after an existing stand is destroyed (Jones 1975). For centuries, fire apparently was the common regenerative force, but in recent years, wildfires have been virtually eliminated. Thus, most of the aspen stands in the central Rockies are mature and overmature. Clearcut logging, another effective regenerative procedure, has not been used extensively in aspen, primarily because of low demand for its wood products.

Realization that mature and overmature aspen now prevalent may be replaced by other plant communities has increased interest in determining its values for various uses. Aspen as wildlife habitat is of particular interest, because little quantified information is available about aspen-wildlife relationships, except that the trees, individually and in stands, appear to be important to many species.

In a larger study,[2] one method of regeneration—clearcutting in 5-acre blocks—was evaluated for its effects on the suitability of an aspen stand as habitat for selected game and nongame wildlife species. This note reports on the short-term response of aspen regeneration to the clearcutting.

Study Area

The work was conducted near Slater Creek, on the Bears Ears Ranger District of the Routt National Forest, in northwest Colorado. The study area, on a west facing slope, consisted of about 45 contiguous acres of aspen encompassing all or parts of several clones. Elevations averaged about 8,200 feet, and topography was undulating, with occasional, steep pitches typical of slumpy landforms. Soils were deep Argic Pachic Cryoborolls.[3]

[1]*Principal Wildlife Biologist, U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station; headquarters in Fort Collins, in cooperation with Colorado State University.*

[2]*Data on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

[3]*Soil data on file at the Supervisor's Office, Routt National Forest, Steamboat Springs, Colo.*

The site was occupied by a mature to overmature stand of aspen, ranging from less than 1 inch to more than 20 inches d.b.h. The understory contained small, occasionally dense patches of chokecherry (*Prunus virginiana* L.) and serviceberry (*Amelanchier alnifolia* Nutt.), and scattered snowberry (*Symphoricarpos oreophilus* Gray). Herbaceous cover was nearly complete (fig. 1). The stand represented elements of the *Populus tremuloides/Symphoricarpos oreophilus* and *P. tremuloides/Thalictrum fendleri* habitat types described by Hoffman and Alexander (1980).

The study area was assumed to be suitable spring, summer, and fall habitat for mule deer (*Odocoileus hemionus* Rafinesque), elk (*Cervus canadensis* Erxleben), and other game and nongame birds and mammals that typically utilize such sites. Domestic sheep also grazed the site each summer.

Methods

For the regeneration study reported here, data were collected from the four, square, 5-acre blocks to be clearcut within the 45-acre study area. Sampling was conducted in square, 1-acre plots centered in each 5-acre block. The 1-acre plots were gridded to provide 25 sampling sites spaced 52 feet apart.

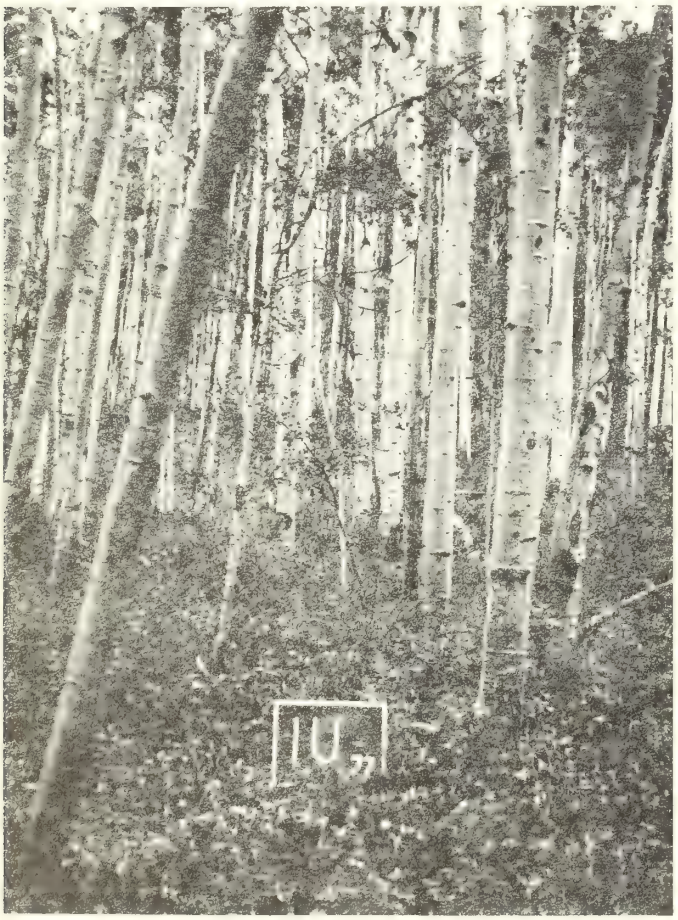


Figure 1.—Typical view on Bears Ears study area before clearcutting.

Pretreatment overstory data were obtained from 2-milacre, circular subplots centered at each of the 25 sampling points in the 1-acre plots. Numbers, diameters and heights of all trees 1 inch or larger were recorded, and increment cores were taken to determine the age of each sample tree. In addition, aspen sprouts and conifers were counted, and their heights were measured in each subplot. Canopy intercept was recorded at subplot centers using a point-sampling device.

Pretreatment sampling was completed in July 1977. Blocks were clearcut, and the downed trees were piled around the perimeter of each block, in early October. All trees were cut except for two mature individuals per acre that were retained for wildlife use. Tractor yarding disturbed the surface of much of the clearcut area, but care was taken to protect aspen roots by keeping the tractor blade above ground level. Several attempts to burn the piled logs in succeeding years were mostly unsuccessful.

Posttreatment data were collected each year in circular, half-milacre, permanently marked plots at the locations described.

Data were subjected to analyses of variance, and means were separated according to Tukey (Snedecor 1961) as appropriate. Confidence intervals were used to indicate reliability of these mean values.

Results and Discussion

The original stand averaged about 180 square feet per acre of basal area distributed on 531 stems per acre (table 1). About half of the trees, 281 per acre, were in the merchantable size classes (≥5.5 inches d.b.h.). This was also the class considered to include the mature and overmature trees (≥70 years). Site index was estimated to be 75 according to curves published by Jones (1967).

The stand was mostly intact, with few down trees and snags. Dead trees totaled 25 per acre, with a mean diameter of 6.1 inches d.b.h.. Several mature conifers were present on the blocks, and a few small, heavily browsed subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) were scattered through the stand.

Percentages of stems containing decay were about evenly distributed among diameter classes, but the total basal area of defective material was obviously much greater among the larger trees.

Although smaller trees constituted almost 50% of the total number, it is highly unlikely that they would have succeeded as stand replacements as the older trees died, because many were badly deformed and most had very sparse canopies. Also, most understory sprouts were multistemmed or bushy and in generally poor condition.

Few sprouts were evident in July 1978, the year after clearcutting (fig. 2). By September, the estimated number was 18,120 ± 3,280 (table 2). Up to 42 sprouts per half-milacre plot were counted; 99% of the plots were stocked. Virtually all of the sprouts produced during the first three growing seasons were present the first year after clearcutting.

Although impressive, the number is much smaller than those described in Utah by Baker (1925), up to

een, Alan W., and Theodore S. Setzer. 1974. The Rocky Mountain timber situation, 1970. USDA Forest Service Resource Bulletin INT-10. 78 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

uell, G. E., and L. L. Loope. 1974. Relationships among aspen, fire, and ungulate browsing in Jackson Hole, Wyoming. U. S. Department of Agriculture, Forest Service, Intermountain Region. 33 p. Ogden, Utah.

offman, George R., and Robert R. Alexander. 1980. Forest vegetation of the Routt National Forest in northwestern Colorado: A habitat type classification. USDA Forest Service Research Paper RM-221, 41 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

nes, John R. 1967. Aspen site index in the Rocky Mountains. Journal of Forestry 65(11):820-821.

nes, John R. 1975. Regeneration on an aspen clearcut in Arizona. USDA Forest Service Research Note RM-285, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Reynolds, Hudson G. 1969. Aspen grove use by deer, elk, and cattle in southwestern coniferous forests. USDA Forest Service Research Note RM-138, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Sampson, Arthur W. 1919. Effect of grazing upon aspen reproduction. U. S. Department of Agriculture, Bulletin 741. 29 p. Washington, D.C.

Schier, George A., and Arthur D. Smith. 1979. Sucker regeneration in a Utah aspen clone after clearcutting, partial cutting, scarification, and girdling. USDA Forest Service Research Note INT-253, 5 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Smith, Arthur D., Paul A. Lucas, Calvin O. Baker, and G. W. Scotter. 1972. The effects of deer and domestic livestock on aspen regeneration in Utah. Utah Division of Wildlife Resources, Publication 72-1. 32 p.

Snedecor, George W. 1961. Statistical methods applied to experiments in agriculture and biology. 534 p. The Iowa State University Press, Ames.

110,000 per acre; Sampson (1919), 85,000 per acre; or Schier and Smith (1979), 52,000 per acre, but is reasonably close to the 14,000 found by Jones (1975) in Arizona. The number is also much lower than the 30,000 first-year sprouts per acre estimated on a study area in southwestern Colorado.[2]

After three growing seasons, sprouts had declined to 8,160 ± 1,560 per acre, a loss of 55%, and stocking had declined to 81 percent (table 2). Although many sprouts were growing well, many others were overtopped, broken, or scarred, and unlikely to survive much longer (fig. 3).

Heights of dominant sprouts averaged 4.4 ± 0.4 feet after three growing seasons, with the tallest measuring 8.9 feet (table 2). Third-year heights compared favorably with 4-year heights, of 3.4 feet in Utah, reported by Sampson (1919); 4.2 feet by Baker (1925); and 4.6 feet on a southwestern Colorado study area.[2] Bears Ears sprout growth, however, fell far short of the 4-year 10.5 foot average height reported on a better site, in Arizona (Jones 1975).

Several factors have contributed to the decline in numbers of sprouts including damage by animals (table 3). Browsing, thought to be primarily by sheep, has declined since the first year after clearcutting and is considered relatively unimportant to date. However, all sprouts are vulnerable to trampling, and many are still susceptible to damage from browsing. Sampson (1919) and Smith et al. (1972) reported adverse effects of sheep on aspen regeneration. Damage from meadow voles (*Microtus montanus* Peale), first noted in 1979, increased markedly in 1980. Vole girdling usually killed the trees.

Many sprouts were decayed or had prominent stem discoloration which appeared to precede decay (table 2). Nearly all of the affected stems had basal lesions, or callused basal injuries (fig. 4). These could result from factors such as shoot breakage, but more likely are caused by snow bending, or overriding by bands of sheep.

Figure 3.—Above average sprouts during their third growing season.

Figure 4.—Aspen sprouts showing basal injuries and associate stem discoloration.

Table 3.—Damage (in percent) to aspen sprouts in blocks clearcu in 1977, on the Bears Ears Ranger District, northwestern Colorad

Category[1]	1978	1979	198
Browsing	23	14	12
Trampling	0	4	1
Girdling	0	< 1	7
Clipping	0	0	3
Basal injury[2]	1	12	19

[1]*Browsing and trampling by sheep, deer, and elk; girdling b voles; clipping by hares and rabbits (Leporidae).*

[2]*Causes uncertain, possible bending by snow, or overriding b sheep.*

Declines in numbers of stems must occur durin maturation of aspen stands. Although these areas ha more that 8,000 sprouts per acre after three growin seasons, the stocking is still susceptible to hazards suc as sheep, which could, if improperly managed, severel reduce stocking or result in a stand of deformed trees.

Literature Cited

Armstrong, David M. 1977. Ecological distribution o small mammals in the upper Williams Fork basin Grand County, Colorado. The Southwestern Natural ist 22(3):289-304.

Baker, Frederick S. 1925. Aspen in the central Rock Mountain region. U. S. Department of Agriculture Bulletin 1291. 46 p. Washington, D.C.

Flack, J. A. Douglas. 1976. Bird populations of aspe forests in western North America. Ornithologica Monographs 19:1-97.

Table 1.—Characteristics of a stand of aspen trees before clearcutting, on the Bears Ears Ranger District, northwestern Colorado[1]

Characteristic	Diameter class (inches)				
	1.0-1.9	2.0-5.4	5.5-10.4	10.5-18.8	All trees
Number per acre	95 ± 34	155 ± 39	158 ± 36	123 ± 34	531 ± 31
Percent with decay	30	35	25	29	30
Stocking (percent)[2]	14 ± 5	24 ± 10	30 ± 10	21 ± 2	67 ± 13
Age (years)	16 ± 2	47 ± 7	67 ± 4	92 ± 6	66 ± 2
Height (feet)	11 ± 1	27 ± 3	59 ± 3	74 ± 2	49 ± 3
D.b.h. (inches)	1.3 ± 0.1	3.8 ± 0.3	7.7 ± 0.3	12.7 ± 0.6	6.7 ± 0.6
Basal area (square feet per acre)	1.0 ± 0.3	12.7 ± 3.7	50.4 ± 12.6	116.4 ± 3.4	180.5 ± 33.7
Percent canopy cover					73 ± 5
Sprouts per acre					473 ± 123

[1]*Confidence intervals* = $\overline{X} \pm t.05\ (S\overline{X})$
[2]*Circular, 2-milacre plots containing one or more trees.*

Figure 2.—July 1978 view of 5-acre block that was clearcut and yarded in October 1977.

Table 2.—Characteristics of sprouts before and after clearcutting in October 1977 in an aspen stand, on the Bears Ears Ranger District, northwestern Colorado[1]

Characteristic	Before cutting	After cutting		
	1977	1978	1979	1980
Number per acre				
Total	473 a	18,120 b	13,200 c	8,160 d
Current year	1 a	18,120 b	580 c	100 d
Discolored or decayed, (percent)	19 a	1 b	7 b	20 a
Stocking (percent)[2]	23 a	99 b	93 c	81 d
Height, (feet)[3]	1.4 a	1.9 a	3.4 b	4.4 c

[1]*Means within each characteristic followed by the same letter are not significantly different at P = 0.05.*
[2]*Circular half-milacre plots containing one or more sprouts.*
[3]*Height of the tallest sprout in each sampling plot.*

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains Southwest Great Plains

Research Note RM-408

June 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Duration of Effectiveness of Carbaryl in Protecting Ponderosa Pines from Attack by Mountain Pine Beetles

W. F. McCambridge[1]

UNIVERSITY LIBRARY
JAN 11 1982
TECH. & AGR. DIV.

Two percent carbaryl spray provided minimally acceptable protection of ponderosa pines from mountain pine beetle attacks 13 months after application. At 4% strength, protection was satisfactory for 15 months, as tested by laboratory bioassay.

Keywords: Carbaryl, tree protection, ponderosa pine, *Dendroctonus ponderosae.*

Management Implications

Although the 4% carbaryl spray proved effective for 15 months in these laboratory tests, field testing under the most rigorous beetle attack pressure would be needed to confirm its efficacy. Furthermore, the Federal Environmental Protection Agency's current (1981) recommendation is for a 2% concentration of carbaryl for the protection of ponderosa pine from mountain pine beetle attacks, and the EPA does not allow an insecticide to be used at a dose rate greater than that recommended on the label.

Introduction

Carbaryl insecticide, under various formulations with molasses or other stickers, applied as a 2% active ingredient (AI) spray, has proven very effective in protecting ponderosa pines, *Pinus ponderosa* var. *scopulorum* Engelm., from lethal attacks of mountain pine beetles, *Dendroctonus ponderosae* Hopkins. The spray is applied annually, usually 1-3 months before the beetle attack period. It would be much more economical if the insecticide could be applied biennially. With this in mind, the residual toxicity of carbaryl, as Union Carbide UCSF-1 formulation,[2] at both 2% and 4% strength, was compared by field and laboratory methods.

[1]*Research Entomologist, Rocky Mountain Forest and Range Experiment Station; headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2]*Now registered as Sevin XLR. The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the USDA, to the exclusion of others that may be suitable.*

Materials and Methods

This study included both a field and a laboratory phase, designed to test residual effectiveness of the sprays for two beetle flight periods under actual conditions. The field test was set up as follows.

Between June 20 and 26, 1979, at each of 25 locations dispersed over about 4 miles within a mountain pine beetle outbreak area at the Manitou Experimental Forest, Colorado, 2 test trees (for a total of 50 uninfested trees) were sprayed with 2% AI carbaryl. About 1 gallon of the insecticide per 50 square feet of bark surface was applied to a height of 30 feet, using garden-type air-pressure spray tanks and extension ladders. During this same period, at each of the 25 locations, 2 additional trees were similarly sprayed with 4% AI carbaryl, and two unsprayed check trees were selected so that they were approximately equidistant from the treatment trees. Thus, 150 trees constituted the total test population. Trees in all treatment categories were of similar diameter and height. Test trees were selected from denser than average stands to increase risk of attack by beetles.

In late July of both years, prior to beetle emergence and attack, two open vials of beetle attractants were placed on each tree in the test. One vial contained 0.5 ml of trans-verbenol; the other, 0.5 ml of myrcene. Attractants were replenished when necessary and remained on all test trees until the end of August. In this way the attraction of all test trees to beetle attacks was maximized.

Sprayed and check trees were examined for evidence of beetle attack during August and September, 1980, approximately 14 and 15 months after treatment.

For the laboratory bioassay, the procedure was as follows:

On July 30, 1980, 13 months after spray application, the treatment trees at one site, which was randomly selected, were cut down. Five 15-inch-long bolts were cut from each tree and taken to the laboratory where, except for the ends, they were encased in 14-mesh screening. Mountain pine beetles emerging from bolts cut from trees that were outside the test area and infested the previous year, were collected and sexed. Thirty females were placed within the screening on each of 10 bolts in each treatment, and the screening stapled shut to confine the beetles. Seven days after the beetles were introduced to the bolts, the screening and bark were removed and the number of beetle attacks counted, the length of the egg galleries measured, and the status of the attacking beetles recorded. This same procedure was repeated for trees cut August 27 (14 months after spraying), and September 26 (15 month postspray).

The test beetles used for the 14-month test were those still emerging from the infested bolts used in the 13-month test. Beetles for the 15-month test were also collected from the same bolts, but were stored at 4° C for approximately 1 month.

Results and Discussion

The field phase of this experiment produced no usable data because of insufficient beetle attacks on either the unsprayed check trees (9 of 48 trees were reached by beetles, which infested 6 of the 9) or on the sprayed trees. The data were inadequate for drawing conclusions of spray efficiency. Pretest sampling of mountain pine beetle density indicated an increasing outbreak trend, as identified by Knight (1960),[3] but beetle attacks failed to occur within the test area.

The laboratory bioassay data are presented in table 1; especially noteworthy is that, throughout the test periods, no beetle was able to make a successful attack on bolts sprayed with the 4% carbaryl formulation. The effective residual protection is, therefore, greater than 15 months.[4] Field testing under the most rigorous beetle attack pressure is needed to confirm the laboratory bioassay.

Two percent carbaryl, as formulated, appears adequate for 13 months of protection, but some risk is involved. The one successful beetle attack would most likely not have been successful had there been a pitch flow, as in most living trees. Unsuccessful attacks do, however, weaken the trees and make them more vulnerable to attacks by *Ips* beetles that eventually kill the trees.

[3]*Knight, Fred B. 1960. Sequential sampling of Black Hills beetle populations. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note 48, 8 p. Fort Collins, Colo.*

[4]*A laboratory bioassay, conducted in 1979 with a different formulation of carbaryl (Sevimol-4) at 4% strength, showed 5 bolts out of 10 sustained successful mountain pine beetle attacks and egg gallery construction after 24 months in the field.*

Table 1.—Laboratory bioassay of residual effectiveness of 2% and 4% carbaryl[1] insecticide[2]

Test duration	Treatment		
	4%	2%	Check
13 months			
Mean number of successful beetle attacks/bolt	0.0	[3]0.1	24.1
Mean percent beetles attacking successfully/bolt	0.0	0.0	80.3
Mean egg gallery length per attack (inches)	0.0	1.5	1.7
14 months			
Mean number of successful beetle attacks/bolt	0.0	1.3	20.4
Mean percent beetles attacking successfully/bolt	0.0	4.3	68.0
Mean egg gallery length per attack (inches)	0.0	2.5	3.5
15 months			
Mean number of successful beetle attacks/bolt	0.0	0.5	15.1
Mean percent of beetles attacking successfully/bolt	0.0	1.7	50.3
Mean egg gallery length per attack (inches)	0.0	2.1	3.5

[1]*Union Carbide UCSF-1, now registered as Sevin XLR.*

[2]*Thirty female beetles were placed on each of 10 logs per treatment. Bioassay was 7 days after beetle placement.*

[3]*Attack did not require ingestion of sprayed bark.*

At 14 months, 2% carbaryl is not considered satisfactory.[5] The average of 1.3 successful attacks per bolt, had they occurred on a standing tree, would certainly have produced attraction that would have reinforced the beetle attack process. The residual deposit of insecticide, while lethal to most attacking beetles, was not adequate to prevent successful attacks under caged conditions.

Results at the end of 15 months seem to indicate either improved protection by 2% carbaryl (unlikely), or another element influencing the data. The latter, in the form of a general weak test population of beetles with some strong individuals, is more likely. These beetles were stored for one month at 4° C before testing, during which period mortality was high. The weakness of the test population is indicated by the fact only approximately 50% of the test beetles made successful attacks compared to 80% of the same population, recently emerged, used for the 13-month residual test (*t*-test indicates significant difference, $P < 0.01$). The strong individual beetles are represented by the egg gallery length in both check and sprayed bolts, which are similar to those from tests a month earlier. Weakening in the test population may also be evident in the 14-month test. This element is not believed to have influenced the validity of the test results.

For future tests of this nature, infested bolts should be stored at 2-4° C until test time, then test beetles will be removed from under the bark just prior to use.

[5]*Carbaryl as Sevimol-4, at 2% strength, was reported to have given satisfactory protection for 2 years in the field on lodgepole pines being attacked by mountain pine beetles. (Personal conservation with Mark McGregor, USDA Forest Service, Missoula, Mont., April 1981.)*

Some argument might be made that the test period included the weathering of trees in September of the second year, when, in actual practice, trees would normally be sprayed in May or June and weather associated with September would be irrelevant as it affected residual spray deposit. It is true that September is usually warmer and drier than May, but this was not considered adequate to materially influence results obtained in this bioassay.

Spraying high value trees every year during the course of a mountain pine beetle outbreak with 2% carbaryl compared to every second year with a 4% concentrate means what, in terms of dollar cost? Assume the commercial application cost for 1.75 gallons of 2% mixed spray per tree is $9.00, including $1.82 for 9.33 ounces of material, and the comparable application cost for 4% spray, is $11.00 per tree. At the end of 2 years, the protection cost per tree using the single application of 4% concentrate would be $7.00 less than if the 2% spray had been used twice. During epidemics, where many thousands of trees may be sprayed annually, the total savings could be impressive.

Results of this test should not be construed as recommending a dose rate greater than presently registered by the Federal Environmental Protection Agency.

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some states have restrictions on the use of certain pesticides. Check your state and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or state extension specialist to be sure the intended use is still registered.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Rocky Mountains | Southwest | Great Plains

Research Note RM-409

June 1981

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

CLEMSON UNIVERSITY LIBRARY
JAN 11 1982
SCI., TECH. & AGR. DIV.

Stream Habitat Improvement and Native Southwestern Trouts

John N. Rinne[1]

Log stream improvement structures in two streams containing Gila trout (*Salmo gilae* Miller) increased physical habitat factors (volume, cover, depth) and positively influenced populations of this endangered trout. Results of analyses of habitat improvement for the Gila trout may have similar management implications for Arizona trout (*Salmo apache* Miller) and for both delisting and developing quality sport fisheries for these two rare southwestern trouts.

Keywords: Habitat improvement, *Salmo gilae, Salmo apache*

Habitat improvement for salmonids began in the 930's when CCC workers constructed thousands of tream improvement structures throughout the United States (Tarzwell 1938, Ehlers 1956). Although the re-ults of these activities have not always been measured, he structures have generally been accepted as having a ositive effect on fishing and the fish resource, and the ractices are used widely in managing trout streams to-ay. Tarzwell (1936) aptly stated, "It is much easier to nstall a so-called improvement than it is to determine whether or not it is beneficial."

Tarzwell (1938) evaluated the effect of stream im-rovement on trout numbers and growth rates and on he aquatic macroinvertebrate fauna in the Southwest. lis investigations disclosed that stream improvements ncreased both the number and pounds of trout based on reel census and the standing crop of bottom organisms. le recommended log dams for improving trout habitat n southwestern streams.

The USDA Forest Service and game and fish depart-ents of Arizona and New Mexico, as the principal man-gers of the habitat and the fish resource in stream en-ironments, have also examined the effects of stream nprovement. These studies have suggested both posi-ve (McKirdy 1963, 1964; Harrison 1962) and neutral Carufel 1964) effects on trout populations and angling.

Since 1977 the USDA Forest Service has been studying the habitat requirements and biology of two native southwestern trouts (Rinne 1977).[2] The Arizona trout (*Salmo apache*) and the Gila trout (*S. gilae*) are currently listed as threatened and endangered, respectively (USDI 1980). Their status results mainly from hybridization and competitive interactions with non-native trouts and chars, principally rainbow trout (*S. gairdneri*), brown trout (*S. trutta*), and brook trout (*Salvelinus fontinalis*). As a result, the two native trouts persist only in extreme headwater tributaries, some of which have, or are suitable for, log-dam improvement structures. While doing basic habitat evaluation for the Gila trout and examining its movements in two streams (McKnight and Main Diamond Creeks) in the Gila National Forest, New Mexico, Rinne (1978, 1980) collected information that permitted limited evaluation of log structures for improving habitat and the trout resource.

Methods and Materials

Data on each habitat and fish resource variable compared are from both natural pools and those created below log-dam structures. Methodology for determination of the trout resource and for delineating the habi-

[1] *Research Fisheries Biologist, Rocky Mountain Forest and Range Experiment Station, Tempe, in cooperation with Arizona State University. Headquarters is in Fort Collins, in cooperation with Colorado State University.*

[2] *Rinne, John N. 1977. Habitat requirements, biology and distribution of the native Arizona (*Salmo apache *Miller) and Gila (*Salmo gilae *Miller) trouts. Rocky Mountain Forest and Range Experiment Station, Study Plan RM 1710-62. 29 p. Tempe, Ariz.*

tat are discussed in Rinne (1978). Basically, the procedure follows these steps: (1) Block pools with nets and electrofish three times, (2) record numbers, lengths, weights, and total biomass of fish, (3) compute surface area from measurements of parallel and perpendicular transects, (4) estimate pool volume and depth statistics from depth measurements on transects, and (5) compute the area of instream and streambank cover from dimension measurements. Habitat and the fish resource in natural versus artificial pools were compared by an unpaired T-test.

Results

In McKnight Creek, there was significantly more volume (unpaired T-test; $P = 0.05$) in artificial than in natural pools (table 1). This was not true in Main Diamond Creek. The remaining three habitat variables (cover, maximum and mean depth) were significantly different ($P = 0.01$) between natural and artificially created pools in both streams. In Main Diamond Creek, number and biomass of Gila trout paralleled improved habitat, and both were significantly greater ($P = 0.01$) in log-structure than in natural pools. By comparison, in McKnight Creek biomass and mean and maximum size of trout were significantly greater ($P = 0.05$) in pools below log structures.

In different terms, volume was 50% to 70% greater in pools created by stream improvement structures in the two streams than in naturally occurring pools. In Main Diamond Creek, cover was seven times as great in artificial pools as in natural pools. In McKnight Creek, cover in artificial pools was over 1.5 times greater than in natural pools in that stream. Mean depth of pools below structures (27 cm) compared to natural pools (14 cm) was twice as great in Main Diamond Creek and 38% to 50% greater in McKnight Creek. There were 1.5 times more Gila trout and 2.25 times the biomass in artificially created pools in Main Diamond Creek as in natural pools. Biomass was twice as great in McKnight Creek in log-dam as in natural pools, but the number of fish was on an average only 30% greater. Mean and maximum size of fish in both streams were, on an average, 20% greater in artificial than in natural pools.

Discussion and Management Implications

The Gila trout is basically a pool fish, and cover and volume and depth of pools have been demonstrated to be positively correlated to both number, size, and biomass of this species of trout (Rinne 1978). Any increase in these three physical habitat factors should positively affect the species in terms of numbers and size of individuals. This occurred in the two streams studied in New Mexico. That is, there was more basic physical habitat below log structures, and twice as many Gila trout occupied these artificial pools. In addition, in small headwater tributaries in the Southwest, pools appear very important to both the native trouts in times of drought and harsh winter weather.

Cover has been widely documented as beneficial to trout (Boussu 1954, Wesche 1976, Binns and Eiserman 1979). The doubling of cover in McKnight Creek and seven-fold increase in this variable in log-dam pools in Main Diamond Creek contributed to increased Gila trout populations.

Size of Gila trout has been positively correlated with maximum depth of pools (Rinne 1978). Maximum and mean size of Gila trout was greater (ca. 25%) in created pools compared to natural pools, in part because of the 40% to 100% greater mean and maximum depth of the former. The positive relationship between maximum depth of pool and maximum size of Gila trout could have important management implications relative to a future sport fishery for this now-endangered trout. That is, reclamation of downstream waters (with deeper pools) or introductions of Gila trout into lakes (as has been done with Arizona trout) may be desirable. The Arizona trout normally attains a length of less than 200 mm in stream

Table 1.—Comparison of habitat and the fish resource of natural pools and those created by stream improvement structures in Main Diamond and McKnight Creeks, Gila National Forest, New Mexico

Characteristic	Main Diamond Creek ($DF = 13$)[1]		McKnight Creek ($DF = 28$)[1]	
	Artificial pools	Natural pools	Artificial pools	Natural pools
Habitat	$\bar{x} \pm 1SD$			
Volume (m^3)	3.45 ± 0.85	2.31 ± 0.55	4.67 ± 0.60	2.73 ± 0.43*
Surface area (m^2)	15.37 ± 3.28	15.18 ± 3.41	14.76 ± 0.52	13.51 ± 2.69
Cover (m^2)	2.87 ± 0.35	0.33 ± 0.12**	3.29 ± 0.54	1.26 ± 0.26**
Maximum depth (m)	0.52 ± 0.03	0.25 ± 0.02**	0.57 ± 0.06	0.37 ± 0.03**
Mean depth (m)	0.27 ± 0.02	0.14 ± 0.01**	0.34 ± 0.04	0.21 ± 0.02**
Fish Resource				
Number	28.5 ± 3.8	11.3 ± 1.05**	12.4 ± 1.9	9.5 ± 1.49
Biomass (g)	460 ± 83	141 ± 30**	615 ± 88	319 ± 55*
Maximum size (mm)	185 ± 8	147 ± 10*	257 ± 13	199 ± 8**
Mean size (mm)	117 ± 2.6	98 ± 8.0	164 ± 12	142 ± 4*

[1]*Asterisks indicate significant differences between artificial and natural pools, * means P = 0.05, ** means P = 0.01.*

environments but has attained a length of over 450 mm in Christmas Tree Lake, Arizona (Rinne et al. 1981).

The greater mean size of Gila trout in McKnight Creek (table 1) relative to Main Diamond Creek and the more rapid growth rate in the former stream[3] may be related, in part, to the number of log structures per unit length of stream. Proportionally, Main Diamond Creek contains many more log dams (160 in 11 km) than does McKnight Creek (12 in 9 km). Gila trout in Main Diamond Creek appear to be stunted (Mello and Turner 1980), and this may reflect a response of the fish resource to habitat improvement. Regan (1966) suggested the small size of trout in Main Diamond Creek results from reduced summer flow. Unfortunately, no data are available for comparison between the present population and the population size and structure prior to installation of log dams in the 1930's. Nevertheless, I agree with Carufel (1964) that a few well-placed structures are better than mass installation and would disagree with the reasoning that if a few structures are good, many are better. Jester and McKirdy (1966) reported that stream improvement did not increase growth rate of a stunted population of brook trout. Although a different species, this suggests that the population of Gila trout in Main Diamond Creek is above optimum carrying capacity, and this may, in part, be attributable to excessive habitat improvement.

Based on studies of movement of Gila trout in these two streams relative to another (South Diamond Creek) that lacks stream improvement structures, it appears that log structures may restrict upstream movement of Gila trout.[3] This influence appears to be related to height of structures, but sufficient data have not been gathered to adequately evaluate height of structures versus their ascension by Gila trout. Double-log structures observed in New Mexico may reach a height of a meter or more above the downstream pool created by water plunge. The relationships of height of structure and habitat created (e.g., depth of pool) also are not available. Nevertheless, single-log structures do create excellent pools, are less expensive to construct, are more stable and resistant to destruction during increased streamflow and flooding, and, although not rigorously tested, must be more easily ascended by upstream spawning migrants.

Stream improvement appears beneficial for the habitat and population size and structure of Gila trout in these two small headwater tributaries. Despite this positive note, each stream for which structures are proposed must be evaluated separately. Contrary to most evaluations of such structures, Carufel (1964) did not record any increase in either angling pressure or harvest of trout after stream improvement in one stream in Arizona. Preferably, pre-evaluation should be conducted for stream reaches planned for improvement, including evaluation of fish and aquatic insect populations and general physical-chemical and habitat features such as cover, pool depths, streamside vegetation and pool-riffle ratio. In the headwater streams inhabited by the Arizona and Gila trouts, the often proposed 50:50 pool-riffle ratio may not be appropriate, but rather a 40:60 or even a 30:70 ratio may be optimum for the rearing of macroinvertebrates for fish consumption. I would recommend installation of a few well-placed, single-log structures, observation and evaluation for a designated time period, and then, if feasible, installation of additional structures. Ideally, hydrologists, engineers, fishery biologists, and landscape architects should jointly select sites.

Although habitat improvement through instream devices appears to be very beneficial to the number, size, and biomass of Gila trout, the cost of construction of these devices and their longevity must be evaluated alongside these increases in habitat and the fish resource. Jester and McKirdy (1966) estimated structures installed between the mid 1950's and 1960's cost about $100 each. Today, the costs of installation and maintenance of log structures are much inflated. Estimates for log structures installed in the mid 1970's by the Mimbres Ranger District on Beaver Creek ranged between $600 and $700 per structure.[4] These were single-log structures and suffered a 25% loss in spring 1979 flooding. By comparison, 50% of the structures in McKnight Creek (most double-log) were lost to flooding in the winter of 1978 (personal observation). Surveys by personnel from the Gila National Forest in spring 1979 on Main Diamond Creek showed that 80 of 162 (ca. 50%) of log structures installed in the 1930's were in need of repair. Ehlers (1956) recorded a 75% loss over 30 years. Attrition of stream improvement structures will occur but is largely related to the nature of construction (one versus two logs) (USDA 1969) and perhaps, more importantly, to placement within the stream. Further, for the Gila trout immediate benefits of habitat improvement as yet cannot be realized by the angler because of the endangered status of the species.

Results of research on the effects of stream improvement structures on Gila trout may be applicable to the Arizona trout. However, preliminary habitat analysis in three streams in the White Mountains of Arizona suggests that in contrast to Gila trout, the Arizona trout was not a pool, but a riffle inhabitant. Four of 12 pools sampled contained no Arizona trout compared to only 1 of 11 riffles that lacked trout. A mean of only 2.25 Arizona trout per pool has been recorded in these three streams compared to an average of 7.3 fish per riffle. The number of trout in riffles is significantly greater ($P = 0.01$, $DF = 16$) when compared by an unpaired T-test. However, comparison of cover in the 12 riffles ($\bar{x} = 1.63$ m^2) to that in the 10 pools ($\bar{x} = 0.32$) indicated it also to be significantly greater ($P = 0.01$, $DF = 21$) when compared by an unpaired T-test. The lack of Arizona trout in pools, therefore, most likely resulted from a lack of cover. Based on the occurrence of significantly more cover and Gila trout in pools created by stream improvement structures, it appears that stream improvement also may be beneficial to the Arizona trout. Data do suggest, however, that creating better habitat for Arizona trout might necessitate improvement of riffle habitat and not creation of more pools by log structures.

[3]*Rinne, John N. In preparation. Movements of a rare southwestern salmonid relative to habitat and population density.*

[4]*Personal communication with Eddie Alfred, Range Conservation Officer, Gila National Forest, March 1980.*

Literature Cited

Binns, N. Allen, and Fred M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108(3): 215-228.

Boussu, Marvin F. 1954. Relationship between trout populations and cover of a small stream. Journal of Wildlife Management 18(2):229- 239.

Carufel, Louis H. 1964. Postdevelopment evaluation (investigations). Completion Report F-7-R-7, Arizona Game and Fish Department, Phoenix.

Ehlers, Robert. 1956. An evaluation of stream improvement devices constructed eighteen years ago. California Fish and Game 42(7): 203-217.

Harrison, James S. 1962. Evaluation of stream improvement structures. Report DJ F-22-R-3. New Mexico Game and Fish Department, Santa Fe.

Jester, Douglas B., and Henry J. McKirdy. 1966. Evaluation of trout stream improvement in New Mexico. Proceedings of the Western Association of State Game and Fish Commissions 46:316-333.

McKirdy, Henry J. 1963. Evaluation of stream improvement structures. Progress Report 1. USDA Forest Service, Southwestern Region, Albuquerque, N. Mex.

McKirdy, Henry J. 1964. Evaluation of stream improvement structures. Final Report. USDA Forest Service, Southwestern Region, Albuquerque, N. Mex.

Mello, Kim, and Paul R. Turner. 1980. Population status and distribution of Gila trout in New Mexico. USDI Fish and Wildlife Service Endangered Species Report 6:1-42, appendices. Albuquerque, N. Mex.

Regan, Dånny M. 1966. Ecology of Gila trout in Main Diamond Creek in New Mexico. U.S. Bureau of Sport Fisheries and Wildlife Technical Paper 5:1-24. Washington, D.C.

Rinne, John N. 1978. Development of methods of population estimation and habitat evaluation for management of the Arizona and Gila trouts. p. 113-125. *In* Proceedings of the Wild Trout-Catchable Trout Symposium, J. R. Moring, editor. [Eugene, Oreg., February 15-17, 1978]. Oregon Department of Fish and Wildlife, Corvallis.

Rinne, John N. 1980. Movement and response to flooding by Gila trout, *Salmo gilae*. p. 79 (abstract). *In* Proceedings of the 24th Annual Meeting of the Arizona-Nevada Academy of Science. [Las Vegas, Nev., April 9-12, 1980].

Rinne, John N., Ben Robertson, Ron Major, and Ken Harper. 1981. Sport fishing for the native Arizona trout, *Salmo apache* Miller in Christmas Tree Lake: A case study. *In* Wild Trout II Symposium [Mammoth, Wyo., September 24-25, 1980] Trout Unlimited, Denver, Colo. (In press).

Tarzwell, Clarence M. 1936. Experimental evidence on the value of trout stream improvement in Michigan. Transactions of the American Fisheries Society 66:177-187.

Tarzwell, Clarence M. 1938. An evaluation of the methods and results of stream improvement in the Southwest. p. 339-364. *In* Transactions of the 3rd North American Wildlife Conference [Baltimore, Md., February 14-17, 1938].

United States Department of Agriculture. 1969. Stream improvement handbook. USDA Forest Service, Forest Service Handbook 2609.11. Wildlife Habitat Improvement Handbook, Chapter 10. Washington, D.C.

United States Department of Interior. 1980. Endangered and threatened wildlife and plants. (Republication of lists of endangered and threatened species and correction of technical errors in final rules.) Federal Register 45(99):33768-33781.

Wesche, Thomas A. 1976. Development and application of a trout cover rating system for IFN determinations. p. 224-234. *In* Proceedings of Symposium and Specialty Conference on Instream Flow Needs, Volume II. J. F. Osborn and C. H. Allman, editors. [Boise, Idaho, May 3-6, 1976]. American Fisheries Society, Bethesda, Md.

Mountains Southwest Plains

Research Note RM-410

July 1981

USDA Forest Service
Rocky Mountain Forest and Range Experiment Station

Hail Damage Variation by Seed Source in a Ponderosa Pine Plantation

UNIVERSITY LIBRARY
JAN 11 1982
TECH. & ...

Ralph A. Read and John A. Sprackling[1]

A Nebraska provenance plantation of ponderosa pine was evaluated after a severe hailstorm. Trees sustaining most damage were from Pacific Northwest, Bitterroot Valley (Montana), and southern Rocky Mountain seed sources. Trees from natural stands east of the Continental Divide have crown form and needle characteristics that incur less hail damage.

Keywords: *Pinus ponderosa,* seed sources, crown forms, hail damage

Management Implications

Landowners and foresters planting trees in areas with frequent, violent hailstorms are advised that certain species of trees are more susceptible to hail damage than others. The use of ponderosa pine seed sources from east of the Continental Divide and north of New Mexico is recommended to minimize hail damage.

Introduction

On September 11, 1977, a severe thunderstorm, accompanied by 60- to 90-mile-per-hour wind, heavy rain, and marble-sized hail (U.S. National Oceanic and Atmospheric Administration 1977) struck experimental provenance plantations of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), 3 miles east of Hastings, Nebr. The plantations consisted of trees from 79 seed sources collected throughout the natural range (mostly eastern) of ponderosa pine (fig. 1). The trees were 13 years old (10 years in the field) and averaged 8.6 feet tall. The many dead rabbits, ground squirrels, mice, and other small rodents floating in the water throughout the plantation after the storm were indicative of the storm's intensity.

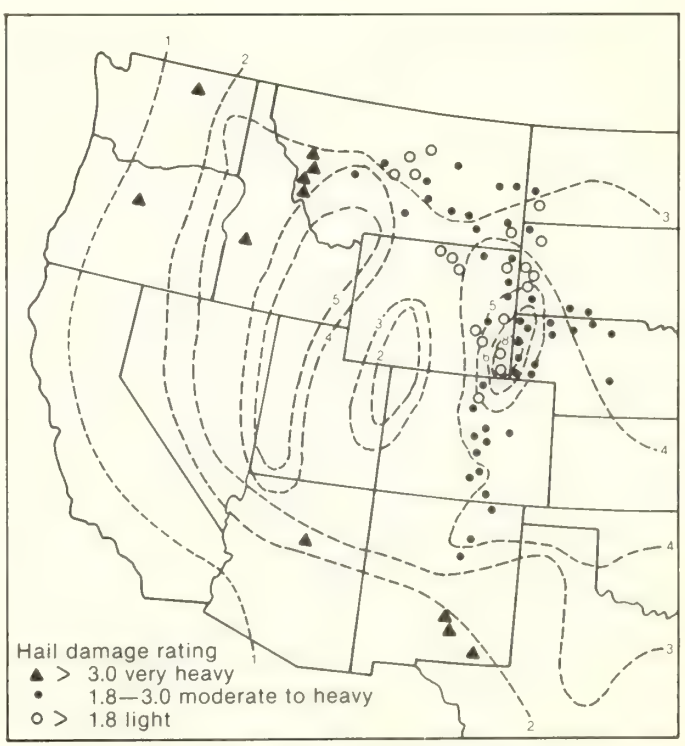


Figure 1.—Dots, circles, and triangles indicate the locations of 79 seed sources of ponderosa pine growing at the Hastings, Nebr., plantation (p). Isohyetal lines indicate average annual number of days with hail based on 200 first-order U.S. Weather Bureau stations, 1899-1938 (U.S. Department of Agriculture 1941).

[1]*Read, now retired, was Principal Silviculturist, and Sprackling is Forestry Research Technician, Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Lincoln, in cooperation with the University of Nebraska. Station headquarters is in Fort Collins, in cooperation with Colorado State University.*

Hail, driven by extreme winds, pelted the trees from a near horizontal trajectory. Damage to the trees was severe, and included loss of needles, bark, and cambium from the northwest side of the trees, the direction from which the storm approached (fig. 2). Piles of needles were found under each tree.

Observations indicated that trees from certain seed sources appeared more damaged than others. Therefore, one of the plantations was evaluated to determine if hail damage varied among the 79 seed sources of ponderosa pine.

Methods

The plantation was established in May 1968 with 2 + 1 bare-root stock. Each of the 79 seed sources is represented by 4-tree linear plots, replicated 15 times in randomized blocks. The plantation, with 30 north-south rows spaced 13 feet apart, covers about 10 acres on an open, level site.

A numerical rating, quantifying the extent of hail damage, was assigned to each 4-tree plot on July 5-7, 1978. The rating was a reflection of damage sustained by the trees on September 11, 1977, and their ability to recover during the first half of the 1978 growing season. A rating of 1 denoted that 0-25% of the original crown foliage was damaged, 2 = 26-50%, 3 = 51-75%, and 4 = 76-100%. Therefore, a rating of 1 indicated light hail damage and 4 indicated very heavy hail damage. Average hail damage ratings were computed for each of the 79 seed sources.

Results

Average hail damage ratings for seed sources ranged from 1.5 to 3.8 (table 1). The plantation average rating was 2.2. Trees of variety *ponderosa* from Oregon Washington, Idaho, and western Montana, and trees o variety *scopulorum* from the southern Rocky Mountai areas of the ponderosa pine range were most heavil damaged. They are exclusively represented by the 1 seed sources having average ratings greater than 3.(and are indicated in figure 1 by solid triangles. Tree from the Okanogan, Wash., source (866) and the Carls bad, N. Mex., source (768) were most heavily damaged with ratings of 3.8 (figs. 3 and 4).

Lightly damaged sources with average ratings of les than 1.8 (indicated by open circles in fig. 1) ar predominately from eastern Wyoming, western Soutl Dakota, and central Montana. The least damaged tree were from the Lewistown, Mont., source (815) and th Windham, Mont., source (753) both rated 1.5.

Because the storm moved through the plantation fron northwest to southeast, trees on the west side and north west corner of the rectangular plantation were damage slightly more than those on the east side and southeas corner. This is reflected in the hail damage ratings whic showed that the westernmost six rows had average hai damage ratings of 2.6 compared to the plantation aver age of 2.2. Because trees of each seed source were ran domly located within the 15 blocks of the plantation, th storm's direction did not affect the relative difference found among seed sources. Trees from the northwester United States and the southern Rocky Mountains were consistently much more heavily damaged than others, no matter where they were located in the plantation.

Figure 2.—The intense hailstorm removed needles, bark, buds, and cambium from the windward side of this tree, severely damaging it.

Discussion and Conclusions

Differences were observed between the crown form o damaged and undamaged trees. Heavily damaged tree from the Northwest and the Bitterroot Valley in western Montana tended to have narrow, thin crowns with fe lateral branches per unit of stem length (fig. 5). Whe hail hit the crowns of these trees, it penetrated th lateral branches, knocking off bark and destroying th cambium on the northwest side of the main stem. Tree with dense, oval crowns, had many lateral branches pe unit of stem length, denser foliage, and protected mai stems. The brunt of the hail was absorbed by th laterals. Consequently, the main stems sustained les damage to the cambium and were better able to recover.

Other differences between severely damaged an lightly damaged trees appear to be related to needl characteristics. Average damage ratings by geographi areas may be compared with needle measurements taken on 3-year-old seedlings of the 79 seed sources i the nursery (table 2). Seedlings of trees from the North west, Bitterroot Valley, and southern Rocky Mountains, where hail is infrequent, generally have a very lo percentage of appressed needles and 2-needle fascicles. Progenies of trees from these three geographic area have mostly divergent needles (needles growing at righ angles to the branches), with most fascicles having three and, occasionally, four needles. They sustained heav hail damage. In contrast, progenies of trees from the

Table 2.—Average hail damage ratings in field plantation (age 10), compared with seedling needle traits in the nursery (age 3), by geographic areas

Geographic areas seed sources	Number of sources	Average hail damage rating[1]	Seedlings with appressed needles[2]	Seedlings with 2-needle fascicles[2]
			percent	*percent*
Northwest, Washington, Oregon, Idaho	3	3.4	5	1
Bitterroot Mountains, Montana	4	3.4	2	0
Westcentral Montana	3	2.1	13	3
Northcentral Montana	5	1.8	23	19
Eastern Montana, North Dakota	4	1.9	25	20
Southern Montana, South Dakota	9	1.9	28	24
Northcentral Wyoming	4	1.7	27	22
Black Hills, Wyoming, South Dakota	8	1.9	32	29
Northern Nebraska, South Dakota	10	2.3	20	24
Southeast Wyoming, Southwest Nebraska	11	1.9	30	35
Northern Colorado	6	2.2	23	27
Southern Colorado	5	2.2	22	17
Northern New Mexico	3	2.7	12	1
Southern New Mexico, Arizona	4	3.4	6	1
Plantation total means	79	2.2	22	20

[1] *1 = light; 2 = moderate; 3 = heavy; 4 = very heavy.*
[2] *Data from Read (1980).*

parently favored these characteristics in the regions where hail is common and severe.

For comparison, isohyetal lines representing the average annual number of days with hail were superimposed over seed source locations in fig. 1. They indicate that, in general, hail is less frequent in the northwestern states and in the southern Rocky Mountains (native areas of the trees most heavily damaged by hail at Hastings, Nebr.); hail is more frequent east of the Continental Divide, especially in Wyoming. However, these isohyetal lines include no information concerning hailstone size, wind accompanying hail, or number of hailstones falling per unit of area, all of which influence hail damage. Changnon (1978) developed, for portions of the western United States, "hail intensity" ratings which include these three characteristics of hailstorms. He found that there are more hailstorms with more and larger hail stones along the lee side of the eastern Rocky Mountains (i.e., the High Plains from New Mexico to Alberta) than elsewhere in the country. Changnon concluded that this area has the greatest hail intensity in the continental United States. Trees of the 11 most damaged sources originated from areas where hailstorms are both less frequent and less intense. The authors conclude that knowledge of hail intensity in the regions from which seed is to be collected is an essential aspect in the selection of seed sources to be planted in areas of the Great Plains where hail commonly occurs.

This ponderosa pine plantation has recovered remarkably well from the storm. The hail killed only a few trees, and they were all from the highly susceptible northwestern sources. Considerable new needle growth was observed throughout the plantation the first growing season following the storm. Because many of the buds were damaged by hail, new growth has emanated from needle fascicle buds. Buds of this type are latent in needle bases of all pines, and any sudden loss of needles or other shock will activate them (Mirov 1967).

Mortality and damage from the hailstorm on introduced species of conifers growing at the Hastings site were considerably greater than for ponderosa pine. Austrian pine (*Pinus nigra* Arnold) and Scotch pine (*Pinus sylvestris* L.) were severely damaged. Trees in a pitch pine (*Pinus rigida* Mill.) plantation sustained the most damage with approximately 80% mortality. Mortality to eastern redcedar (*Juniperus virginiana* L.), native to the Great Plains, was negligible. In areas with frequent, violent hailstorms, ponderosa pine should be among preferred conifer species for planting, with seed sources from east of the Continental Divide and north of New Mexico most desirable.

Literature Cited

Changnon, Stanley A., Jr. 1978. The climatology of hail in North America. American Meteorological Society Monograph 38:107-128.

Mirov, N. T. 1967. The genus *Pinus*. 602 p. Ronald Press Co., New York, N.Y.

Read, Ralph A. 1980. Genetic variation in seedling progeny of ponderosa pine provenances. Forest Science Monograph 23, 59 p.

U.S. Department of Agriculture. 1941. Climate and man, yearbook of agriculture. 1248 p. U.S. Government Printing Office, Washington, D.C.

U.S. National Oceanic and Atmospheric Administration. 1977. Storm data 19(9).

Weidman, Robert H. 1939. Evidence of racial influences in a 25-year test of ponderosa pine. Journal of Agricultural Research 59:855-887.

Agriculture—CSU, Fort Collins